NIST Smart Grid Interoperability Framework 4.0 Webinar

Chris Greer
Avi Gopstein
Cuong Nguyen

Engineering Laboratory
NIST Smart Grid & Cyber-Physical Systems Office

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NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Review: Energy Independence and Security Act

NIST has *"primary responsibility to* ***coordinate*** *development of a* ***framework*** *that includes protocols and model standards for information management to achieve* ***interoperability*** *of smart grid devices and systems…"*

Agenda

- Background on NIST Smart Grid Interoperability Framework
- Smart grid conceptual model
- Communications pathways scenarios
- CPS ontology for the grid
- Key Framework Messages
  - Operations
  - Economics
  - Cybersecurity
  - Testing & Certification
- Ways to be involved

Review: Interoperability Frameworks to date

NIST Special Publication 1108

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0

Office of the National Coordinator for Smart Grid Interoperability

NIST National Institute of Standards and Technology • U.S. Department of Commerce

2010

NIST Special Publication 1108R2

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0

Office of the National Coordinator for Smart Grid Interoperability,
Engineering Laboratory
in collaboration with
Physical Measurement Laboratory
and
Information Technology Laboratory

NIST National Institute of Standards and Technology • U.S. Department of Commerce

2012

This publication is available free of charge from http://dx.doi.org/10.6028/NIST.SP.1108r3

NIST Special Publication 1108r3

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0

Smart Grid and Cyber-Physical Systems Program Office
and Energy and Environment Division,
Engineering Laboratory

in collaboration with
Quantum Measurement Division,
Semiconductor and Dimensional Metrology Division,
and Electromagnetics Division,
Physical Measurement Laboratory
and
Advanced Network Technologies Division
and Computer Security Division,
Information Technology Laboratory

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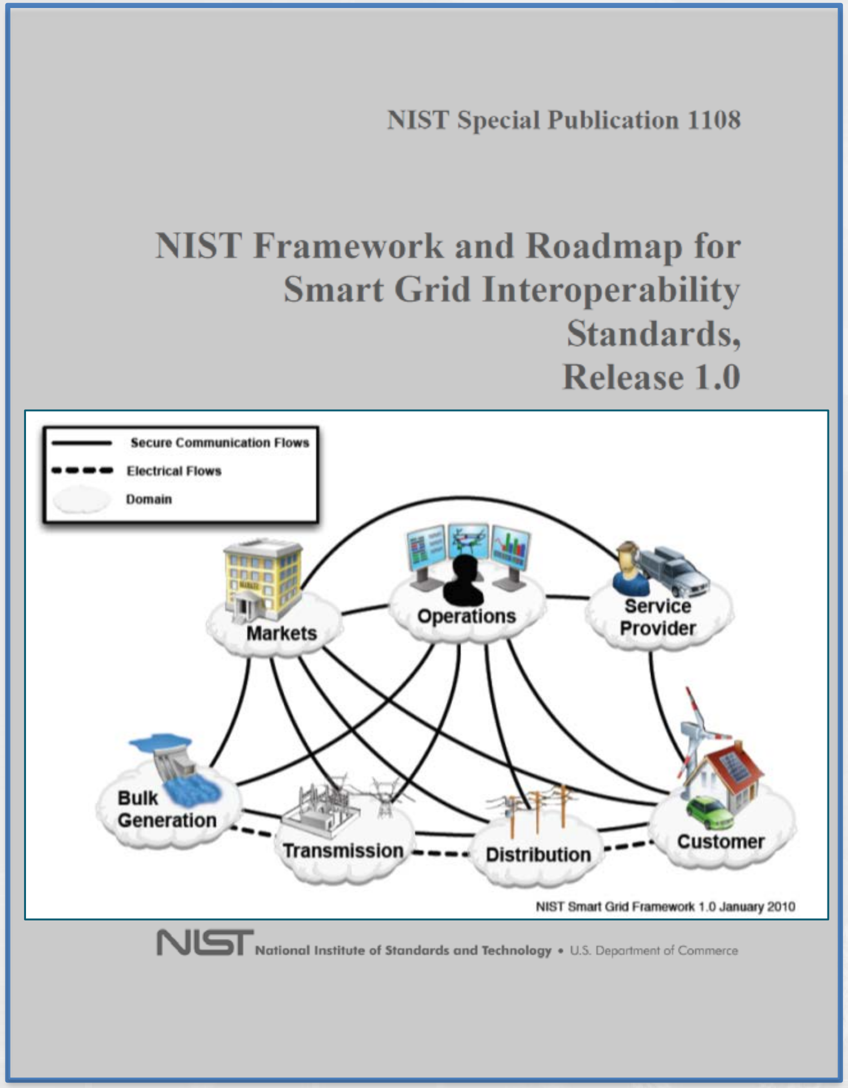
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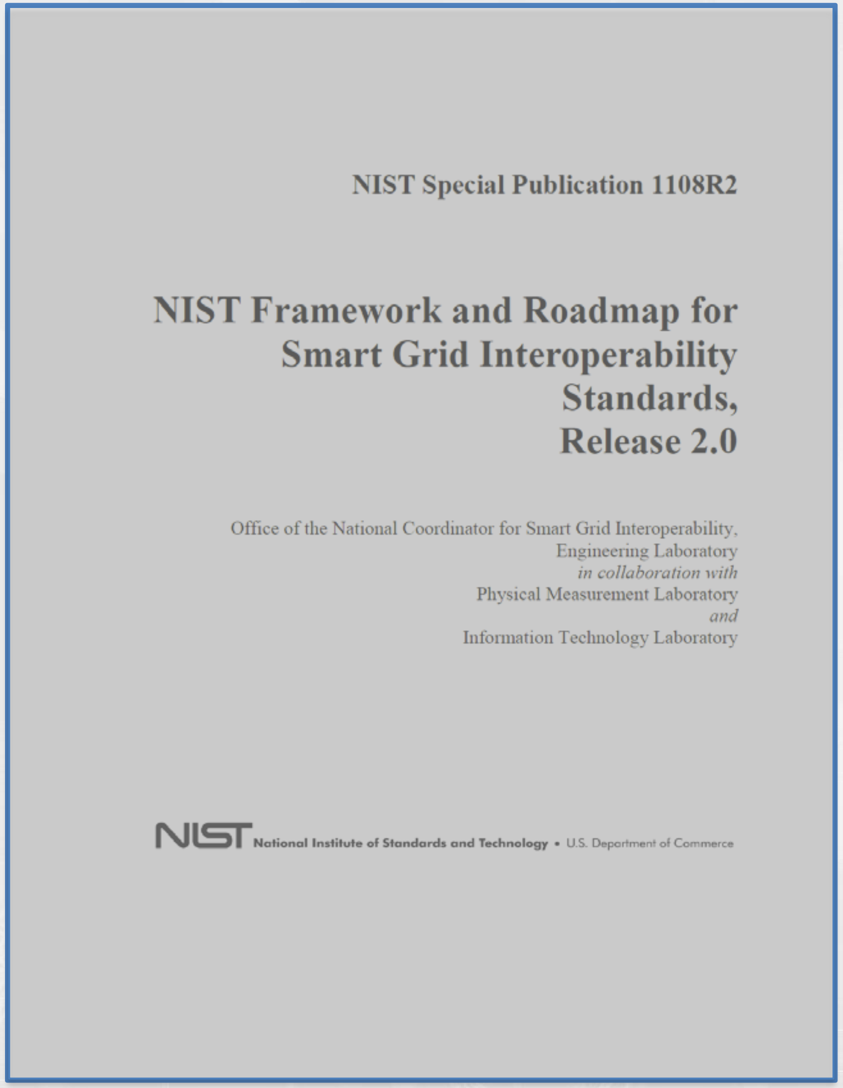
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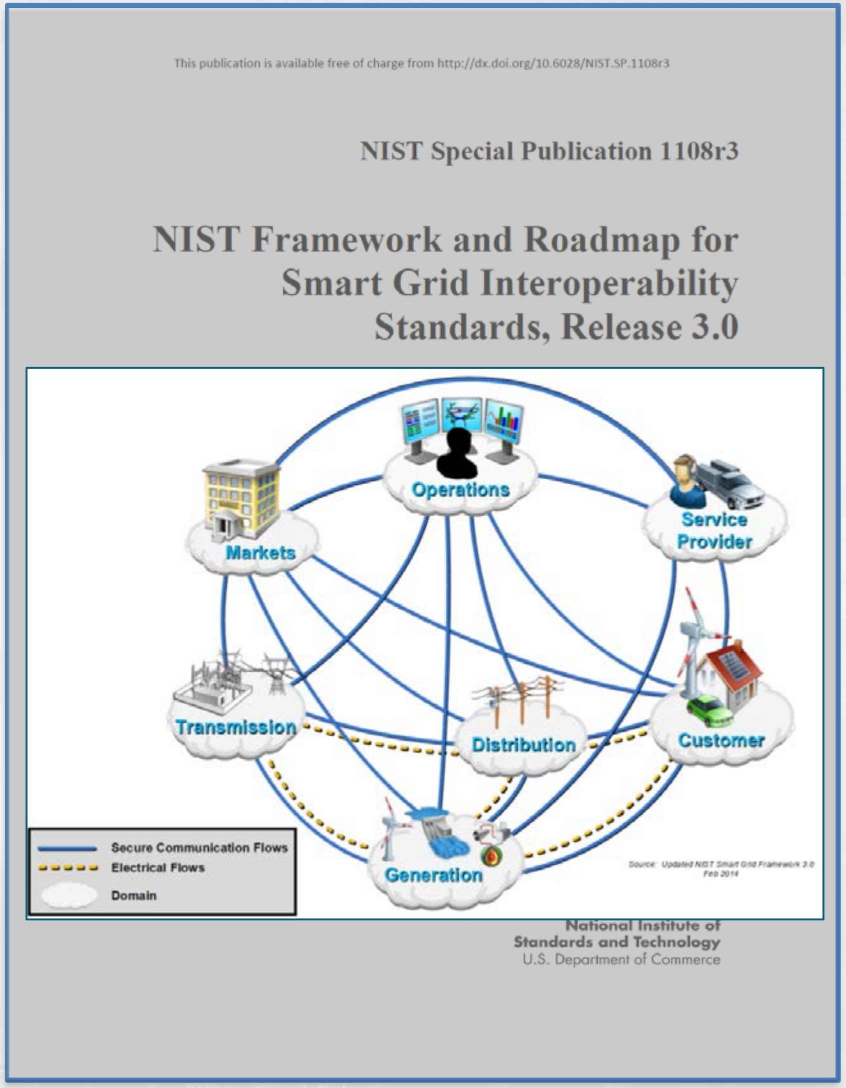
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Motivations / Themes

Motivations

- Technology is advancing rapidly
- Evolving capabilities bring:
  - New opportunities
  - New concerns / challenges
  - Structural change
- Modular and scalable technologies enable:
  - Disaggregation of system physics
  - Hyper-local optimization
  - A new set of cascading concerns
- Distribution models diversifying
- Interoperability more critical than ever
- Interoperability more challenging than ever

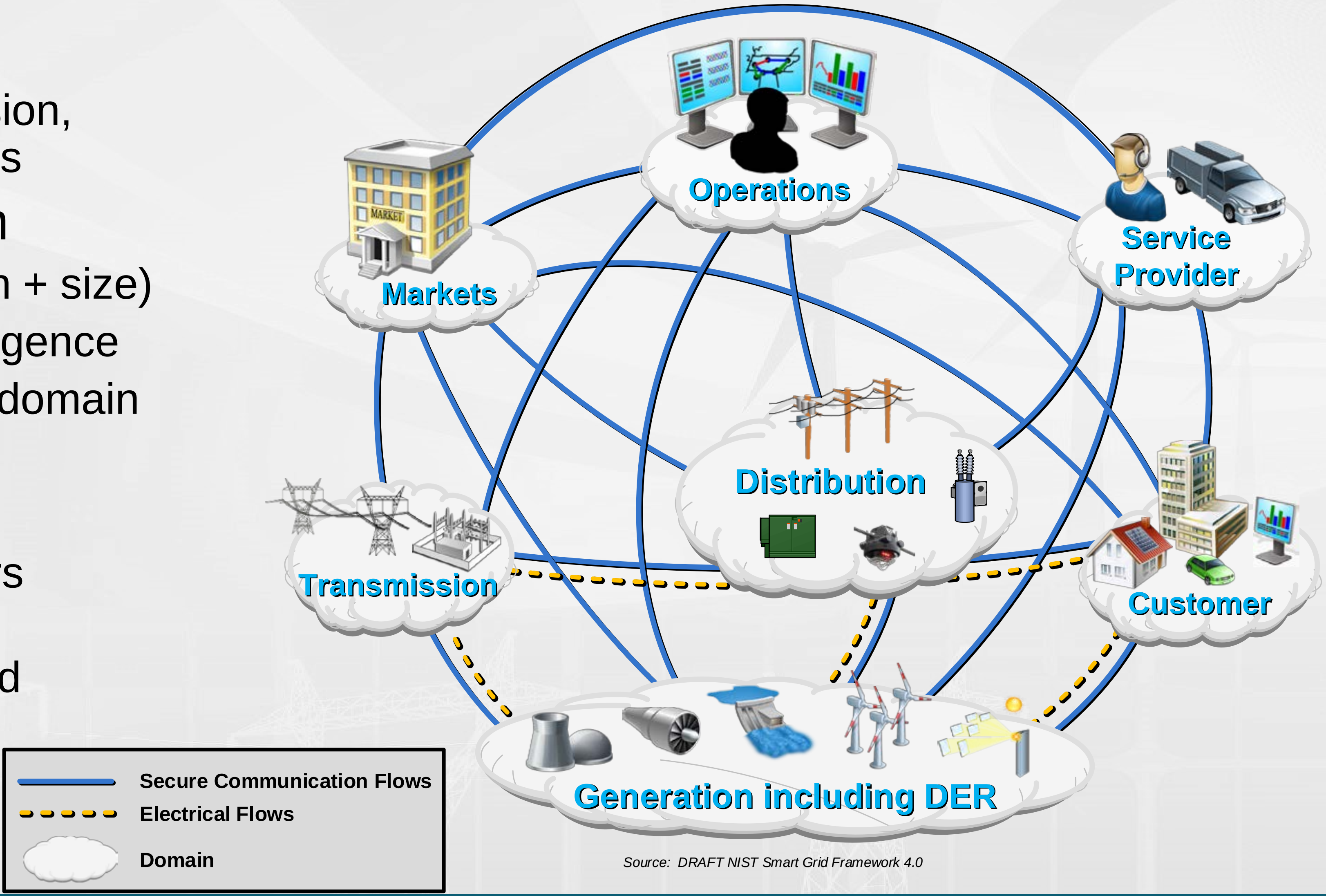
Framework 4.0 Themes

- Structural changes are occurring in the grid
- System complexity is increasing
  - Interoperability is a critical element of modern grid function
- No single architecture is correct
  - Common trends
  - Unique conditions
- Grid architectures affect:
  - Operations
  - Economics
  - Cybersecurity
- As actors take on new roles within the system and new economic forces emerge, interoperability gains new dimensions
  - Testing & Certification

Conceptual Model

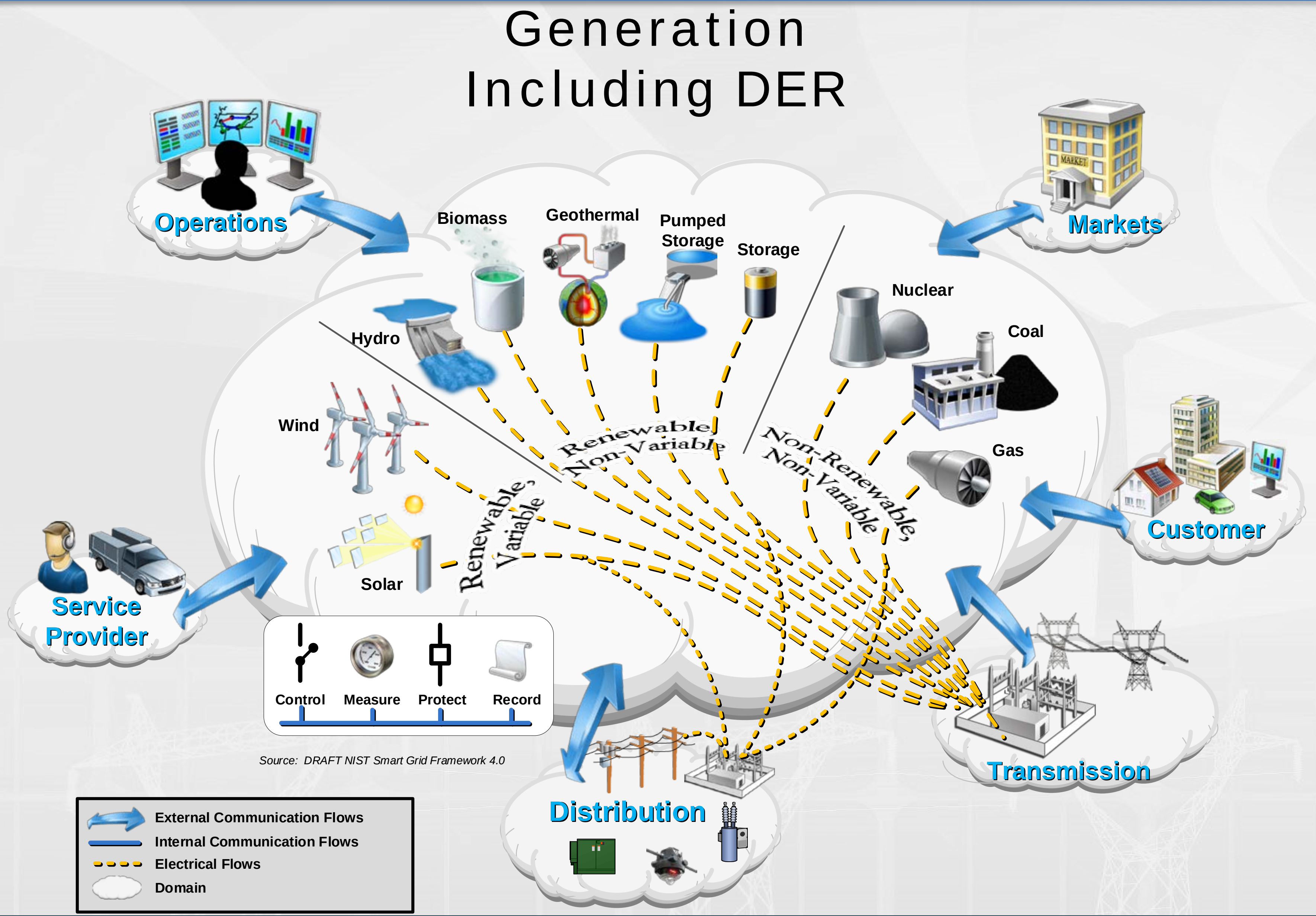
- Generation including DER
  - Technology diversity
  - Physical proximity to transmission, distribution + customer domains
- Intelligent distribution system
  - Increasing importance (location + size)
  - Improved controllability + intelligence
  - Connected to service provider domain (e.g., congestion mitigation)
- Empowered consumers
  - Operations & intelligence enters customer domain
  - Customer diversity incorporated

Smart Grid Conceptual Model



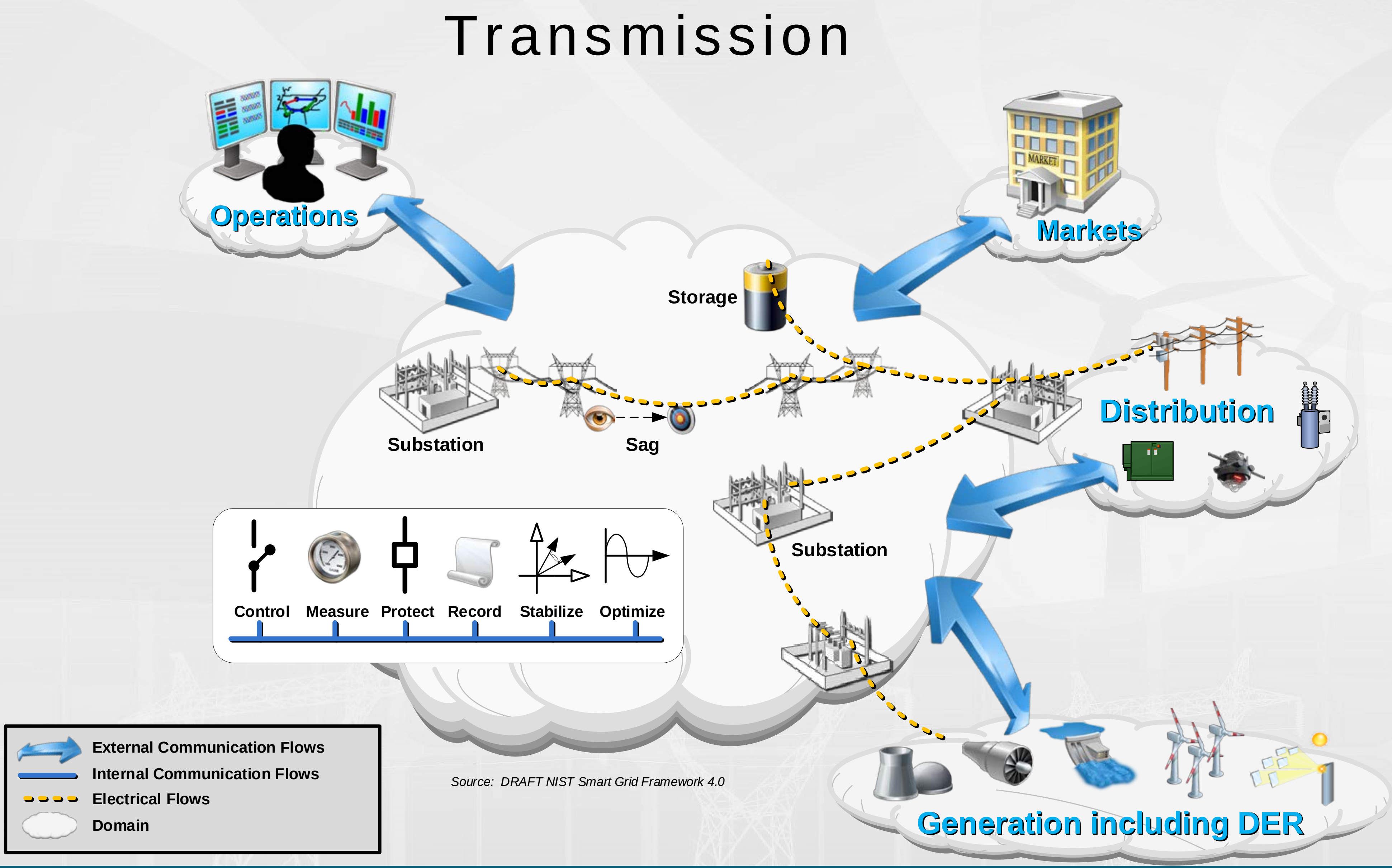
Source: DRAFT NIST Smart Grid Framework 4.0

Generation Domain



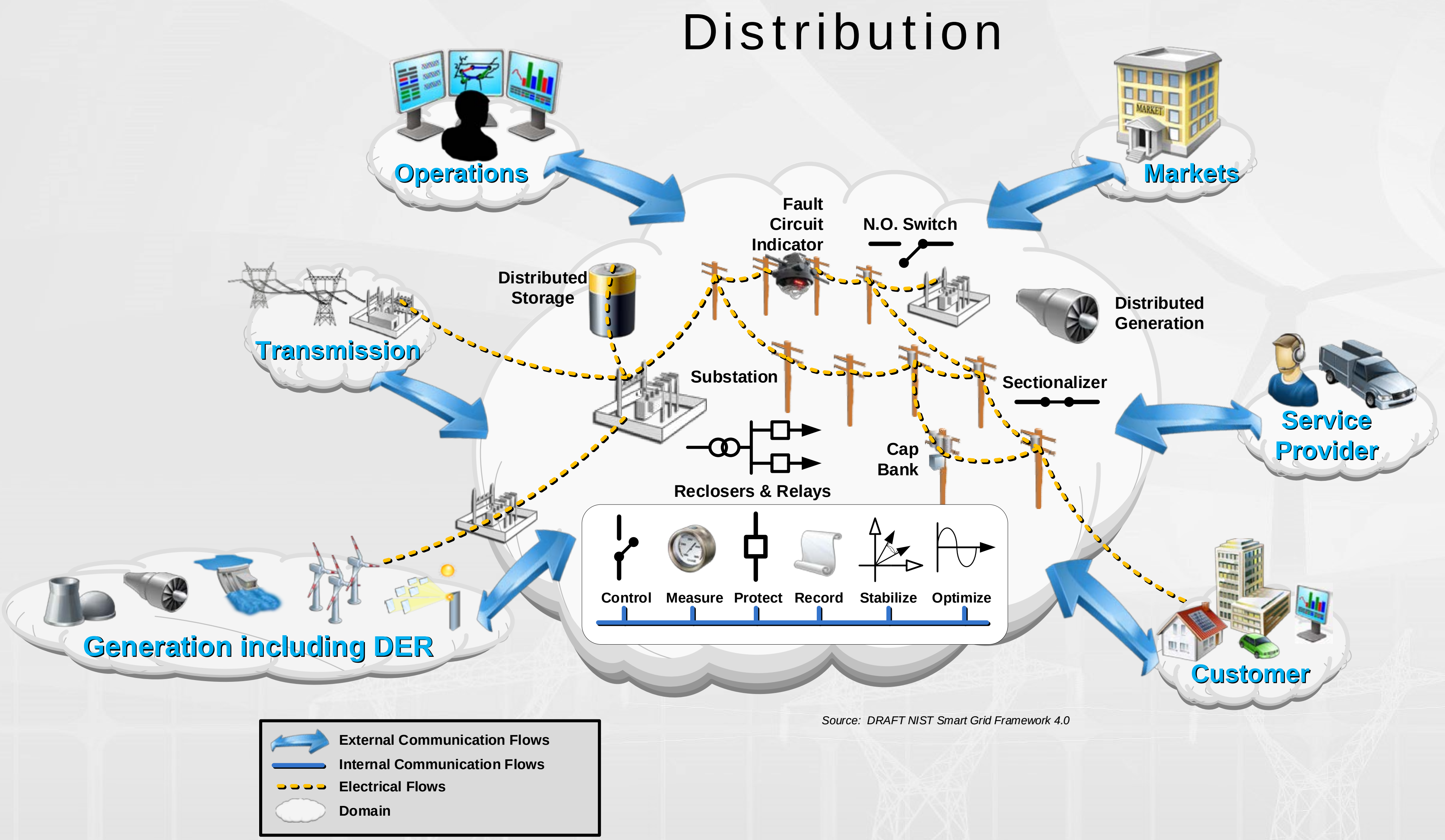
Source: *DRAFT NIST Smart Grid Framework 4.0*

Transmission Domain



Source: *DRAFT NIST Smart Grid Framework 4.0*

Distribution Domain



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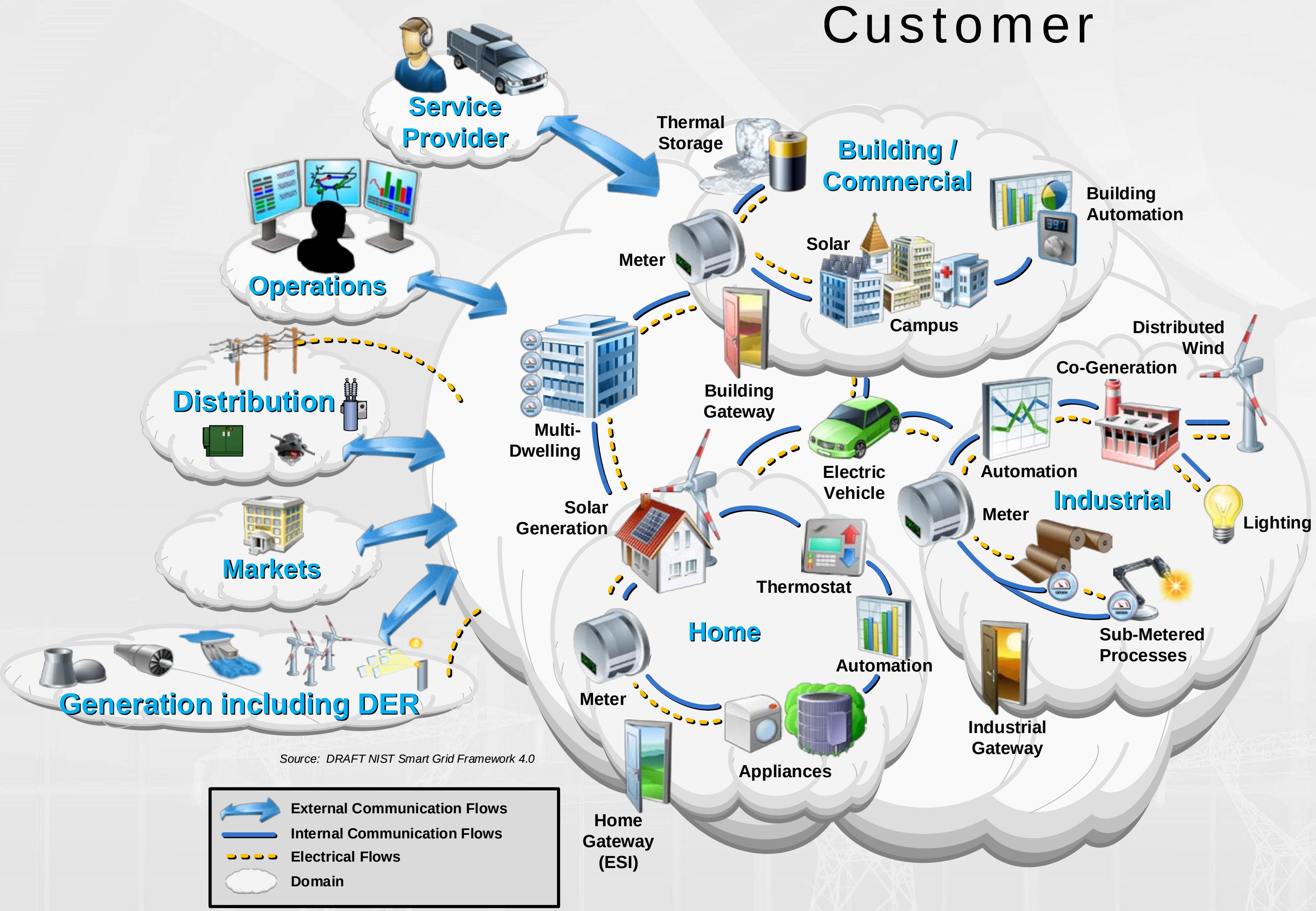
Customer Domain



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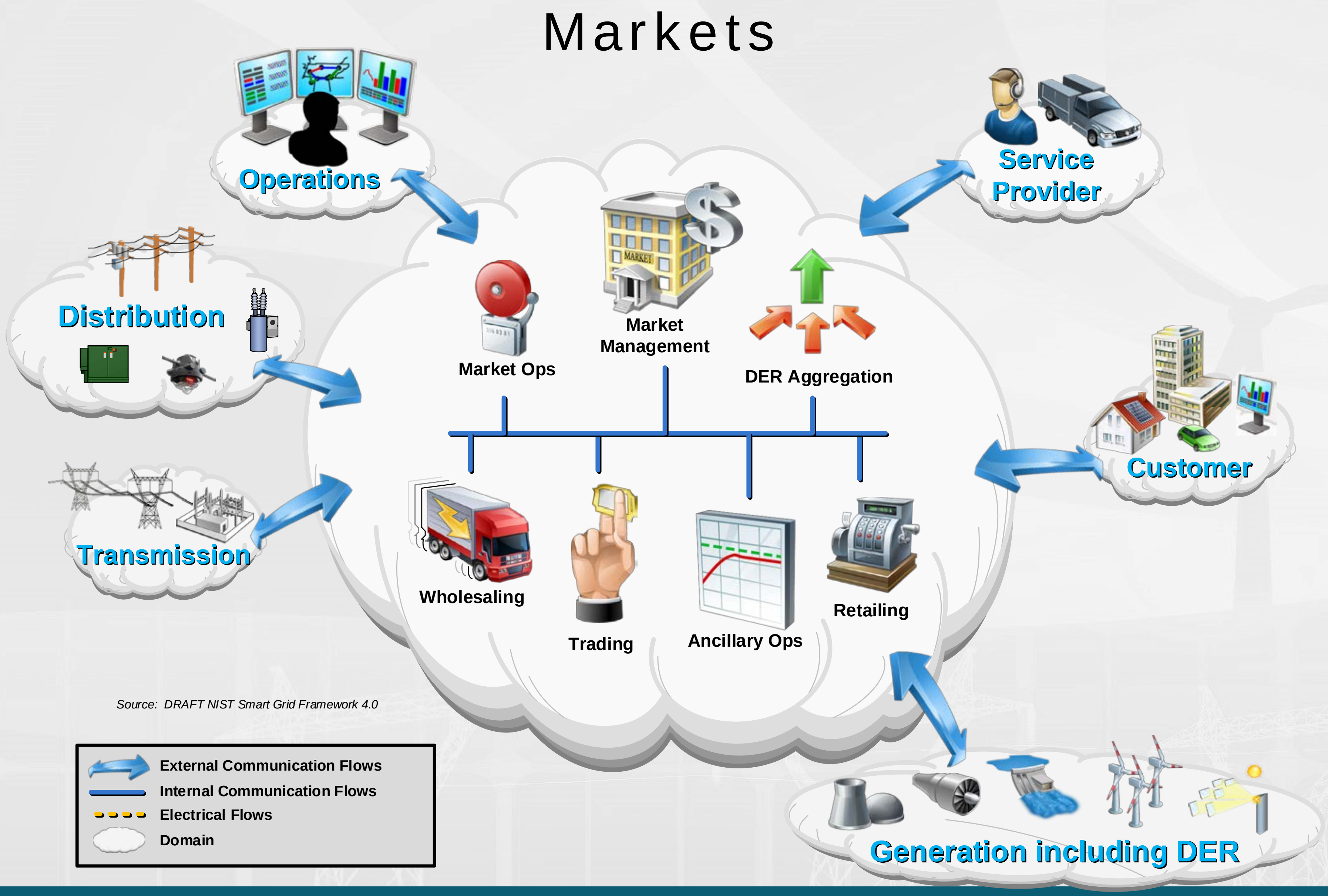
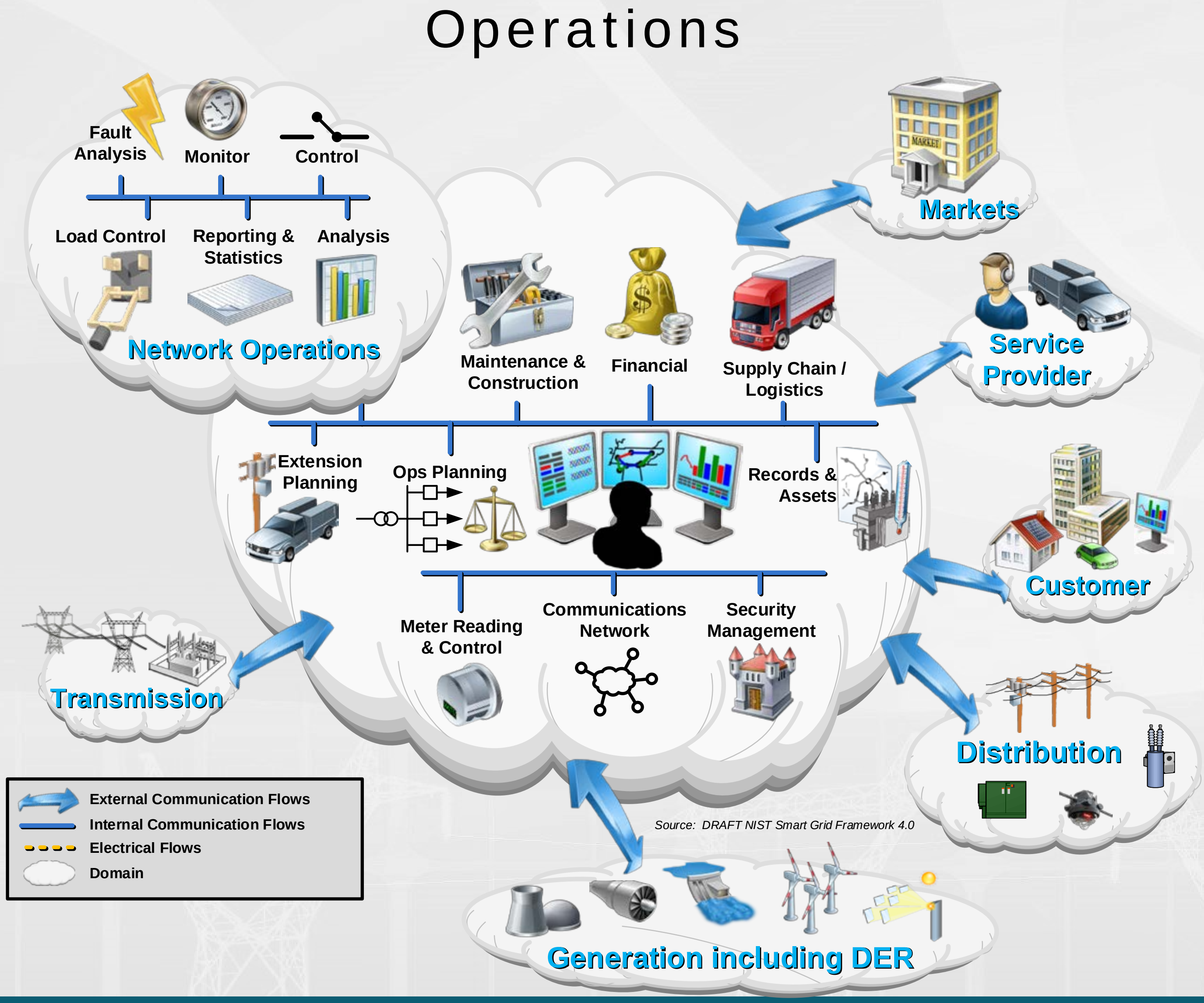
Markets Domain



Source: DRAFT NIST Smart Grid Framework 4.0

Operations Domain



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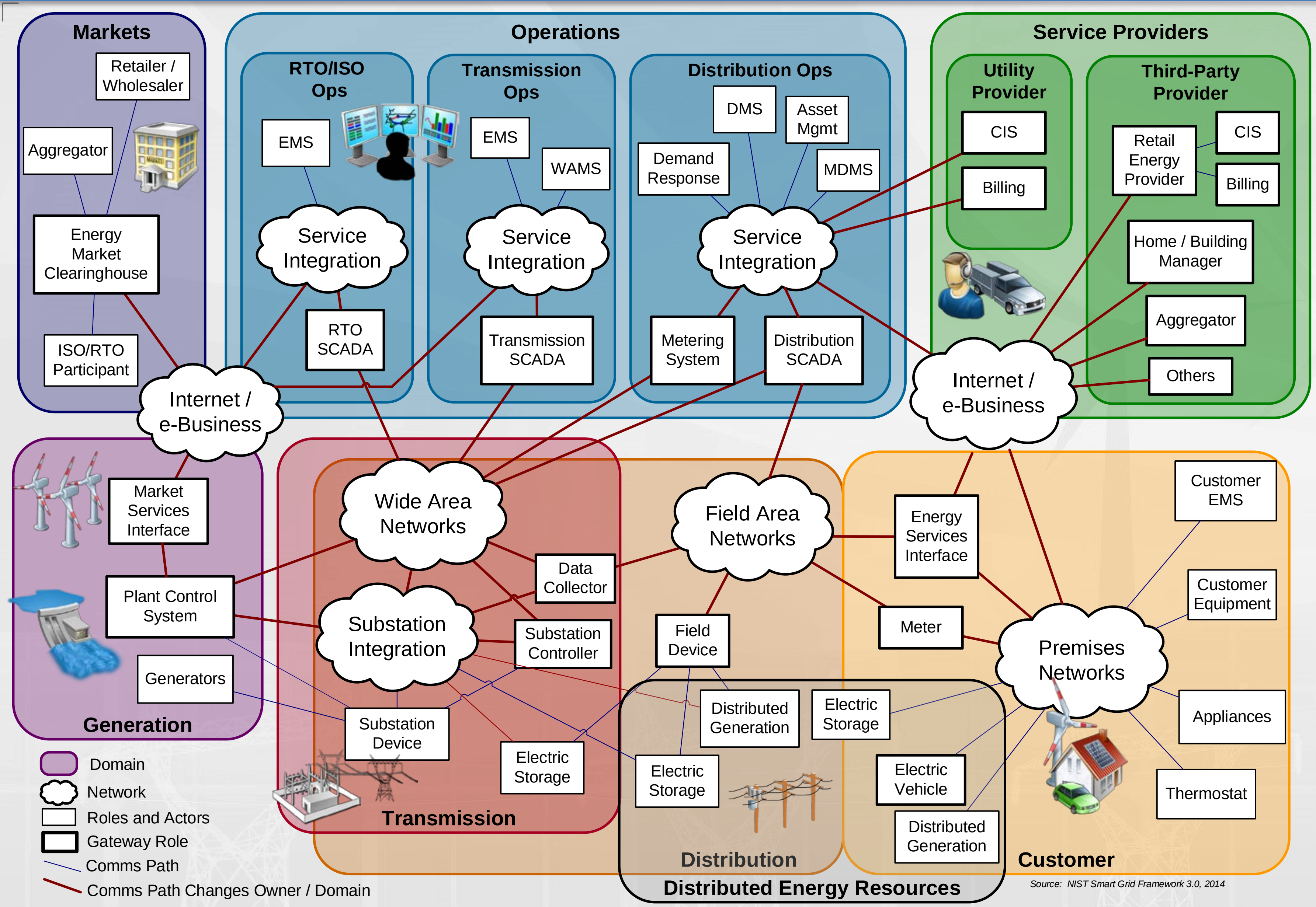
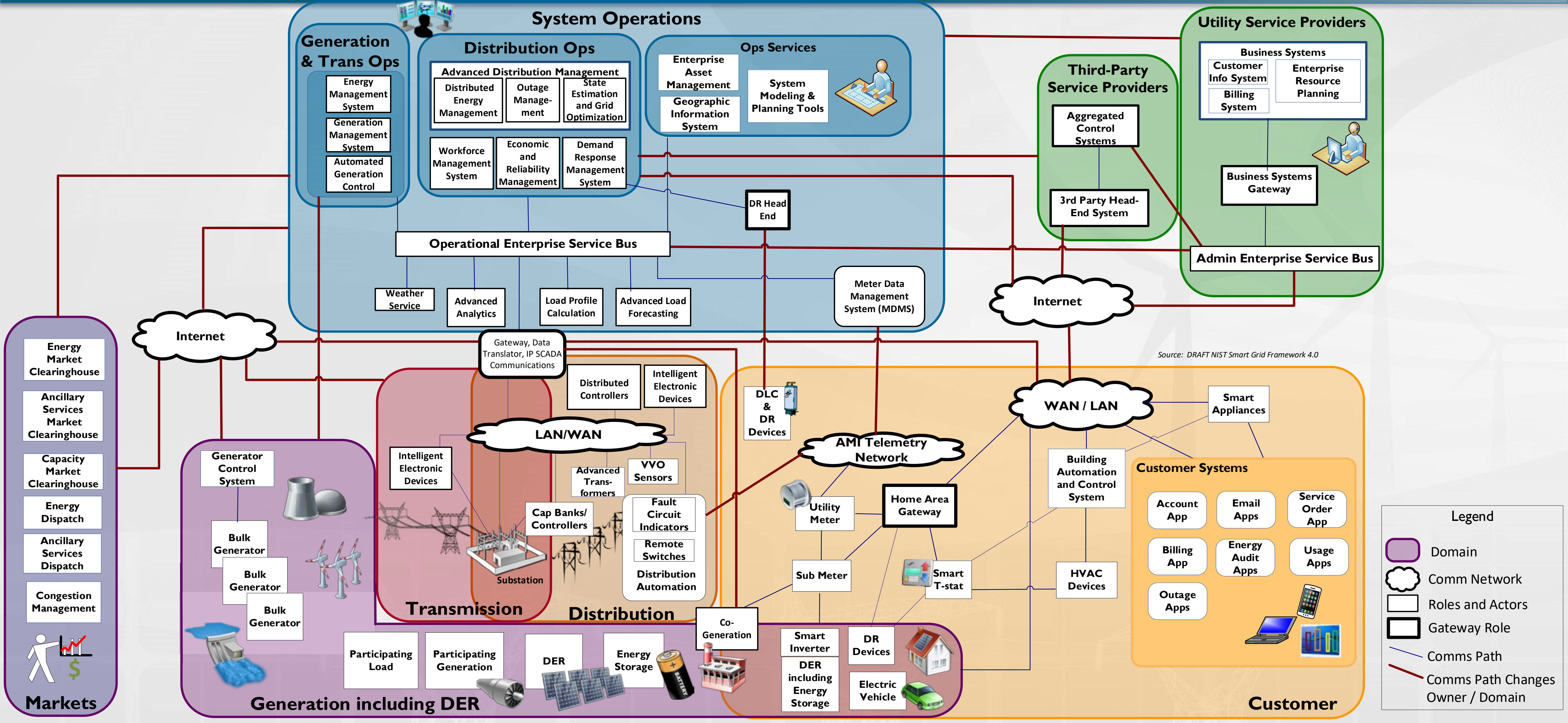
Service Provider Domain

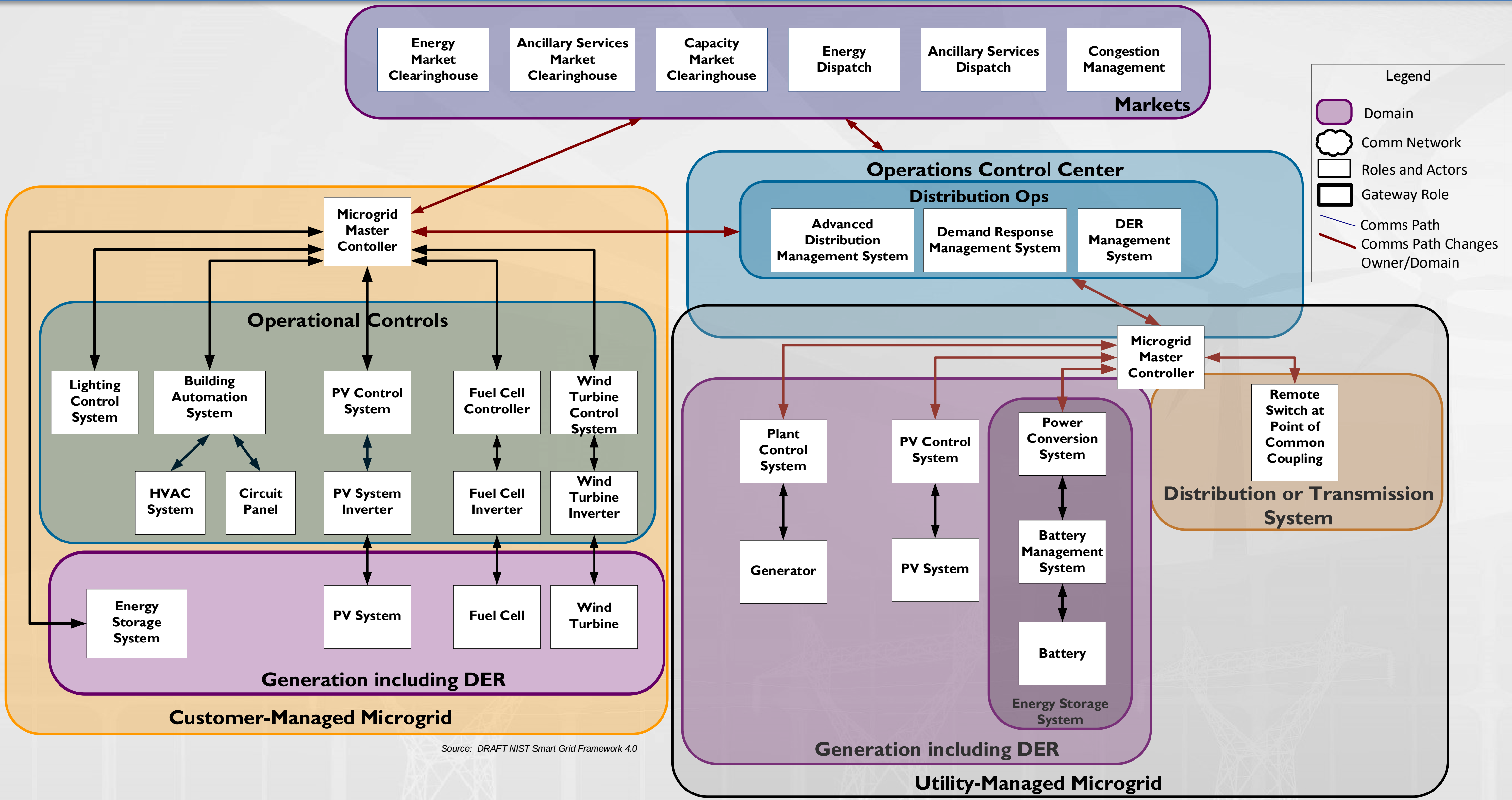
Legacy Communications Pathway Scenario



High-DER Communications Pathway Scenario



Microgrid Communications Pathway Scenario



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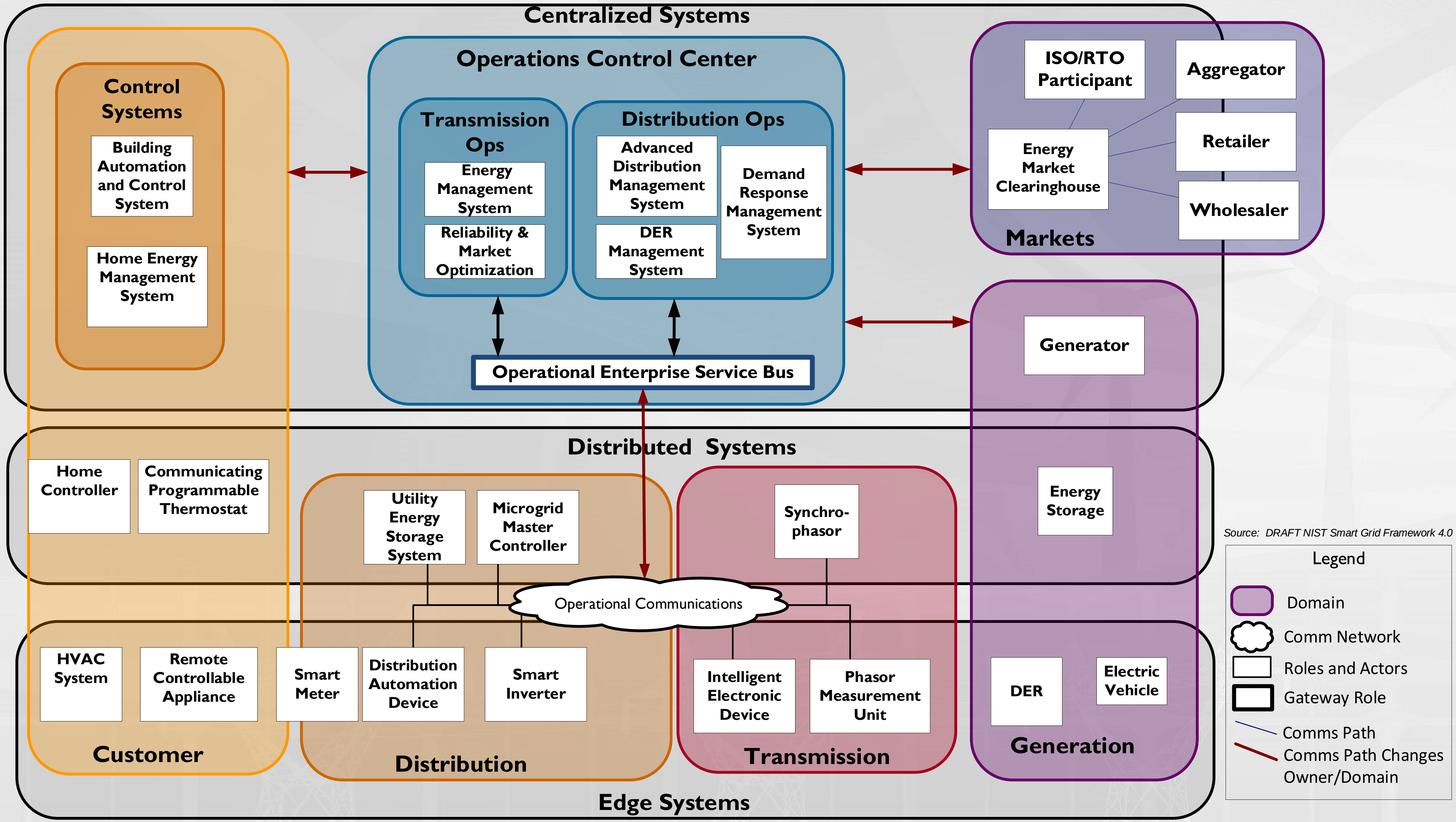
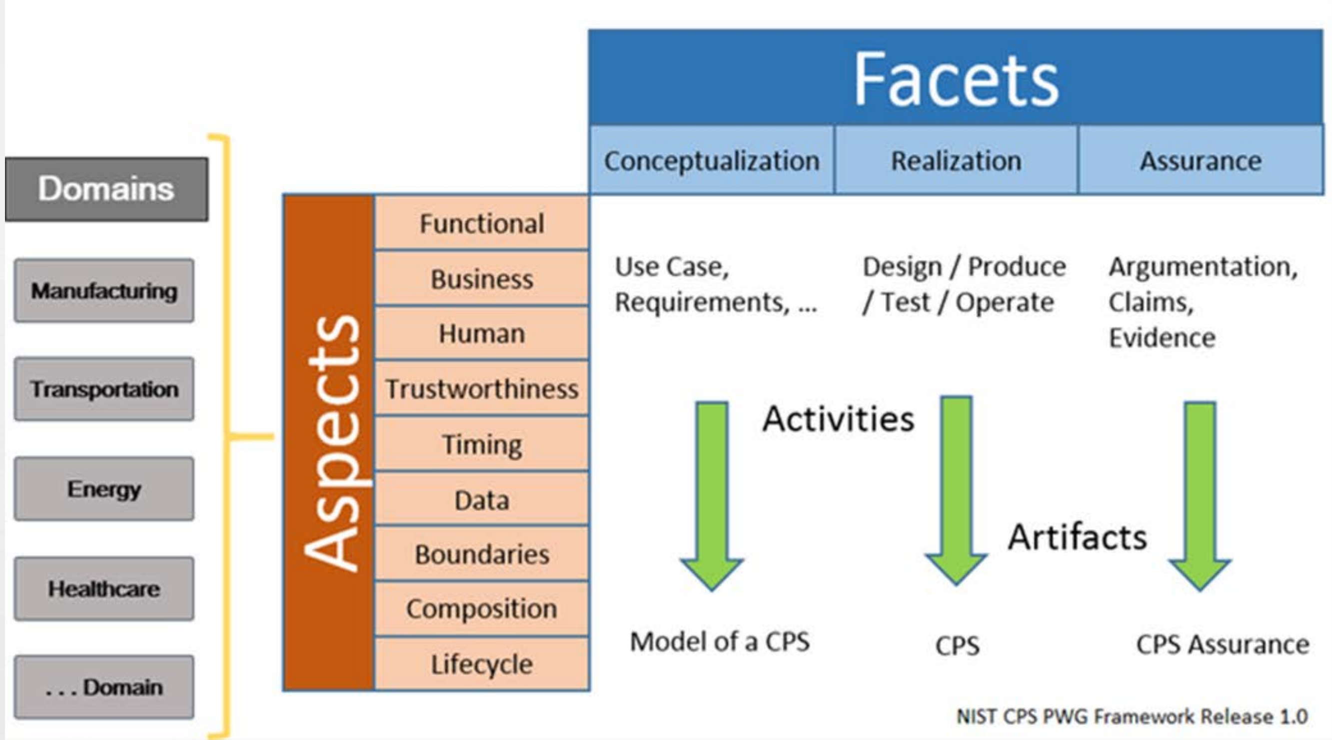
Hybrid Utility Communications Pathway Scenario



The CPS Framework—A Tool for the Smart Grid

Jargon surrounds the electrical grid:

- *Intelligence moving to the edge*
- *Data tsunami*
- *Grid architecture*
- *Cloud / fog computing*
- *Smart grid*
- *Microgrid vs backup power*



The cyber-physical systems (CPS) framework provides a vocabulary of energy sector semantics, or ontology, through evaluation of CPS framework aspects and concerns

CPS Aspects and Concerns

- **Functional**
  - Actuation
  - Communication
  - Controllability
  - Functionality
  - Manageability
  - Measurability
  - Monitorability
  - Performance
  - Sensing
- **Business**
  - Enterprise
  - Cost
  - Environment
  - Policy
  - Quality
  - Regulatory
  - Time to Market
  - Utility
- **Human**
  - Human Factors
  - Usability
- **Trustworthiness**
  - Privacy
  - Reliability
  - Resilience
  - Safety
  - Security
- **Timing**
  - Synchronization
  - Time Awareness
- **Data**
  - Data Semantics
  - Relationship between Data
- **Boundaries**
  - Behavioral
  - Networkability
  - Responsibility
- **Composition**
  - Adaptability
  - Complexity
  - Constructivity
  - Discoverability
- **Lifecycle**
  - Deployability
  - Disposability
  - Engineerability
  - Operability

CPS Aspects and Concerns

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  - Engineerability
  - Operability

INTELLIGENCE

Note: Illustrative only

Description of CPS Concerns for the Smart Grid

Aspect	Concern	Description	Grid Context for CPS Concern	Grid CPS Concern Description	Architecture Significance
Functional	**Controllability**	Ability of a CPS to control a property of a physical thing. There are many challenges to implementing control systems with CPS including the non-determinism of cyber systems, the uncertainty of location, time and observations or actions, their reliability and security, and complexity. Concerns related to the ability to modify a CPS or its function, if necessary.	• Controllability requires the condonation of sensing, processing and acting • Multiple inputs are needed to make control decisions • Most grid control systems and hardware were not designed to accommodate large numbers of DERs. • More dynamic monitoring and control to respond to the dynamic network	• Ability to control grid properties (sense, process and change); e.g., intentionally change a phenomenon / property	• Coordination of sensing and processing functions to produce accurate control signals. • Architectures needs to support control applications that input and evaluate multiple optimization factors including carbon usage and market prices • Architecture needs to support use of group commands (e.g. DNP3 settings groups) and third-party aggregator control of DERs • Architecture support of faster input of sensor data from traditional SCADA devices and newer devices including phasor measurement units (PMUs)
Functional	**Functionality**	Concerns related to the function that a CPS provides	• The constant evolution of the power system creates new grid functions. • Grid control functionality has expanded to include management of generation assets which require different functionality e.g. diverse generation assets require additional control functionality including distributed assets.	• Ability to provide grid functions e.g. control functions, sensing functions, service-related functions.	• Innovative grid technology needed to facilitate Power Markets, DERs, Microgrids, Electric Vehicles, etc. • Architecture needs to support management of DERs constraints that differ from older types of generation.
Functional	**Manageability**	Concerns related to the management of CPS function.	• Need the ability to manage change across multiple devices at different grid levels.	• Ability to manage change internally and externally to the grid at the cyber-physical boundary e.g. digital equipment and actuators affected by EMC	• Communication topology views and key externally visible properties for multi-tier distribution communications needed for system control, substations, field operations, and Transmission/Distribution integration[74]

Framework Themes through pathway scenarios

- Scenarios affect what we think about grid
  - Cybersecurity
  - Operations
  - Economics
- We can use the examples to explore
  - Common trends
  - Changing responsibilities
  - Unique considerations
- Scenarios help us understand value streams
  - Who is the customer in a High-DER architecture?
  - The role of interoperability in unlocking this value
- Testing & Certification growing importance
  - Claimed conformance vs actual performance
  - Actuation and controllability in every device
  - Diversified ownership, unified operation
- CPS ontology allows description and specification

ENGAGEMENT OPPORTUNITIES
Registration info on later slides

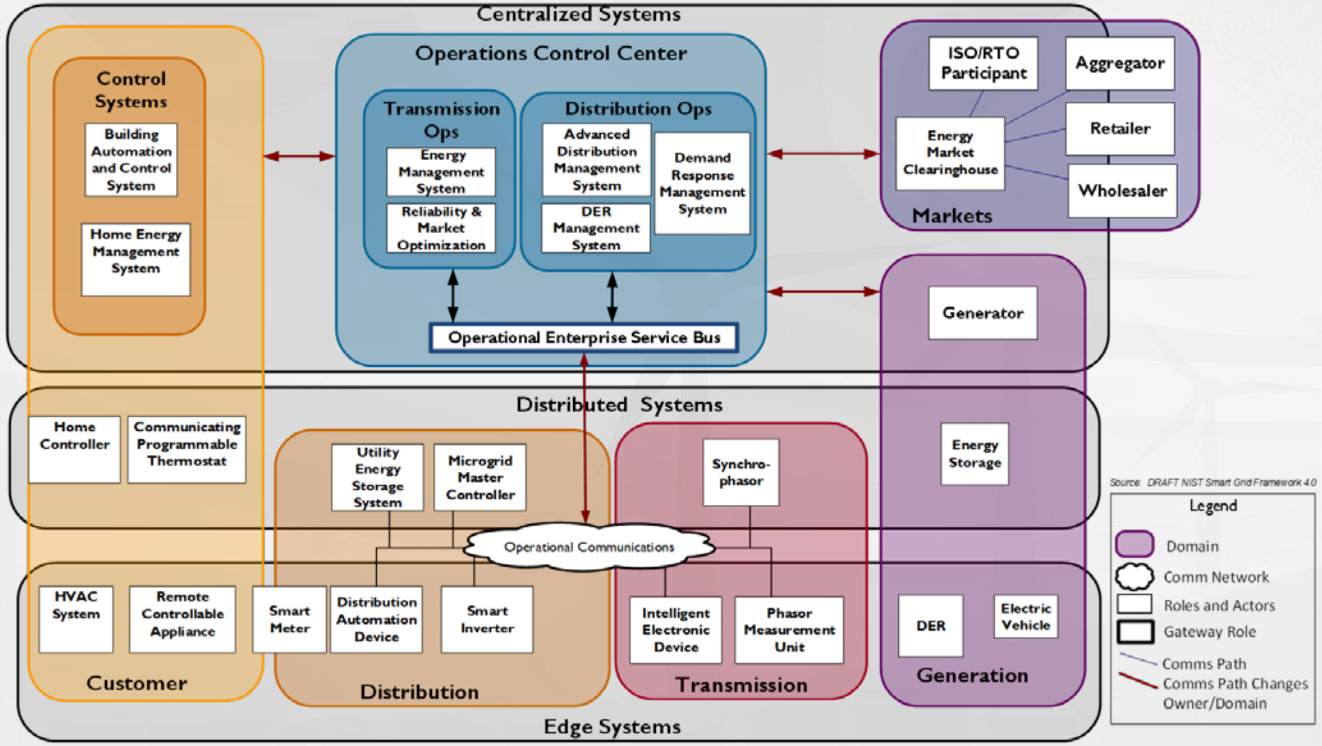
July 9, 2018:
Testing & Certification Workshop
Washington, DC

July 24, 2018:
Communications Pathways & Ontology Workshop
Gaithersburg, MD

August – October, 2018:
Regional operations & economics workshops

Operations Key Message: Migrating to domain edge

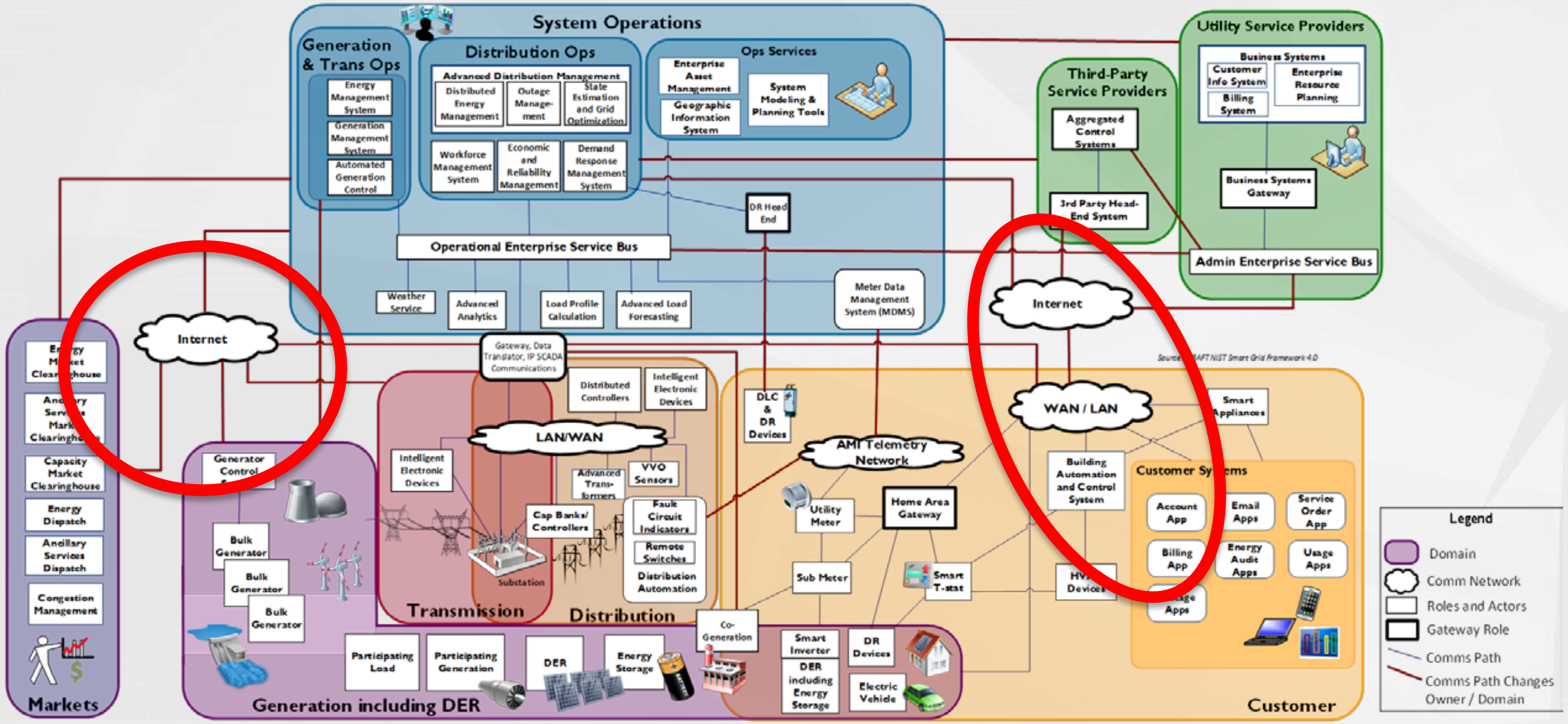
- Sensing, actuation and control is moving towards the grid edge
  - Common trend across all scenarios
  - Occurring in each domain
    - Transmission edge: PMUs and IEDs
    - Distribution edge: distribution automation devices & smart inverters
    - Customer edge: remote controllable appliances
  - Operational efficiencies can be gained through local management



Hybrid Utility Communications Pathways Scenario

Operations Key Message: Shared infrastructure

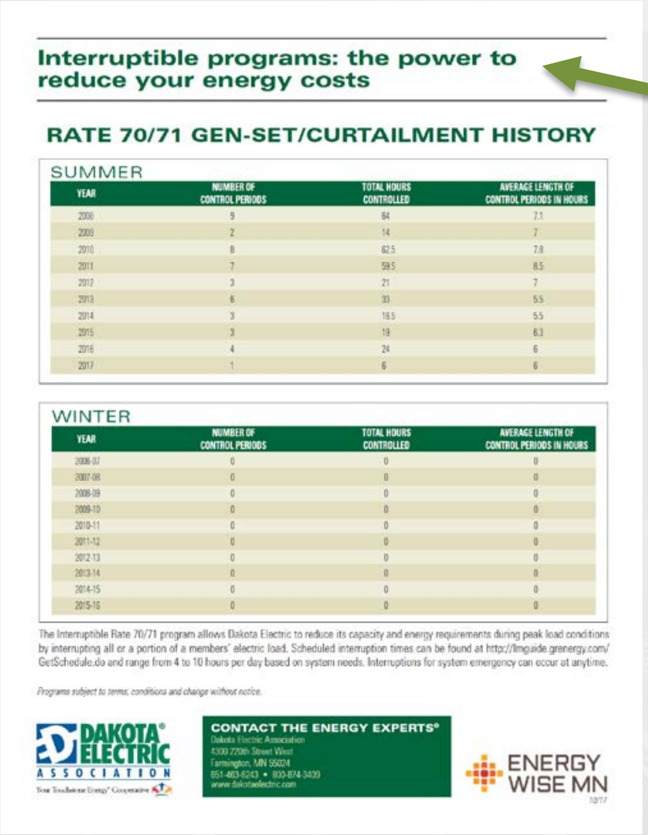
- As DERs increase, shared infrastructure becomes more important



- Shared infrastructure increases need for predictability
  - Physical predictability (e.g., IEEE 1547)
  - Communications predictability (e.g., IEC 61850)
- Shared infrastructure has benefits, possible risks

Operations Key Message: No single implementation

- Grid architectures are not mutually exclusive
- The examples allow us to explore technical aspects of interoperability
- No single architecture is “correct”



Interruptible programs: the power to reduce your energy costs

RATE 70/71 GEN-SET/CURTAILMENT HISTORY

SUMMER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIODS IN HOURS
2008	9	64	7.1
2009	2	14	7
2010	8	62.5	7.8
2011	7	59.5	8.5
2012	3	21	7
2013	6	33	5.5
2014	3	16.5	5.5
2015	3	19	6.3
2016	4	24	6
2017	1	6	6

WINTER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIODS IN HOURS
2006-07	0	0	0
2007-08	0	0	0
2008-09	0	0	0
2009-10	0	0	0
2010-11	0	0	0
2011-12	0	0	0
2012-13	0	0	0
2013-14	0	0	0
2014-15	0	0	0
2015-16	0	0	0

The Interruptible Rate 70/71 program allows Dakota Electric to reduce its capacity and energy requirements during peak load conditions by interrupting all or a portion of a members' electric load. Scheduled interruption times can be found at http://lmguide.grenergy.com/GetSchedule.do and range from 4 to 10 hours per day based on system needs. Interruptions for system emergency can occur at anytime.

Programs subject to terms, conditions and change without notice.

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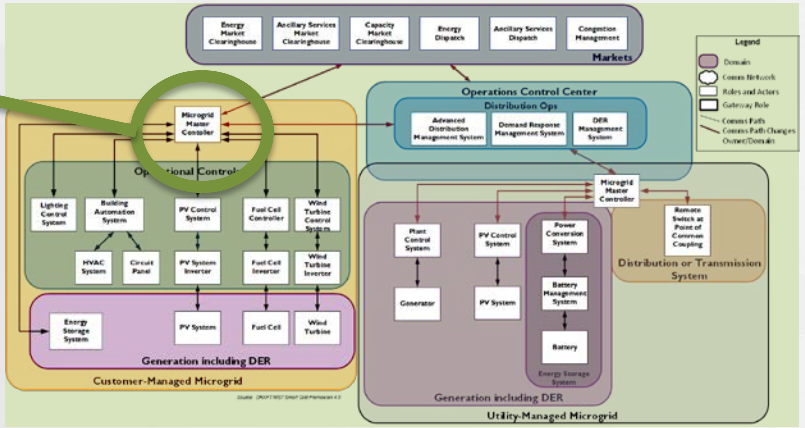
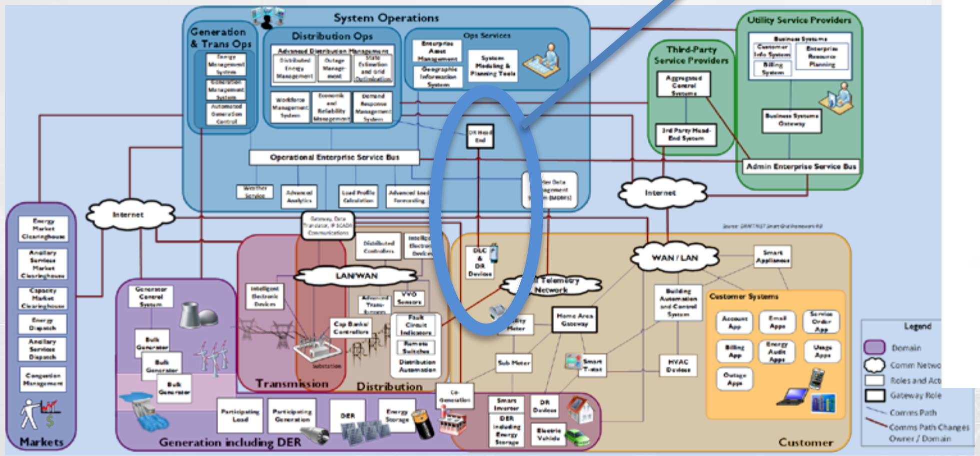
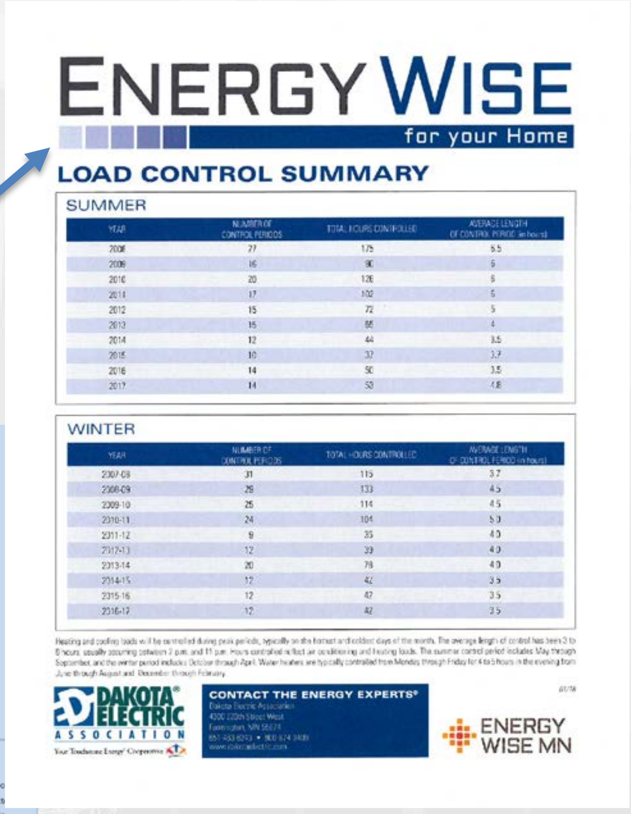


Hybrid Utility Communications Pathway Scenario

High-DER Communications Pathway Scenario





ENERGY WISE for your Home

LOAD CONTROL SUMMARY

SUMMER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIOD (in hours)
2008	27	175	6.5
2009	16	90	5
2010	20	126	6
2011	17	102	6
2012	15	72	5
2013	15	65	4
2014	12	44	3.5
2015	10	37	3.7
2016	14	50	3.5
2017	14	53	4.8

WINTER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIOD (in hours)
2007-08	31	115	3.7
2008-09	29	133	4.5
2009-10	25	114	4.5
2010-11	24	104	5.0
2011-12	9	35	4.0
2012-13	12	39	4.0
2013-14	20	79	4.0
2014-15	12	42	3.5
2015-16	12	42	3.5
2016-17	12	42	3.5

Heating and cooling loads will be controlled during peak periods, typically on the hottest and coldest days of the month. The average length of control has been 3 to 6 hours, usually occurring between 2 p.m. and 11 p.m. Hours controlled reflect air conditioning and heating loads. The summer control period includes May through September, and the winter period includes October through April. Water heaters are typically controlled from Monday through Friday for 4 to 5 hours in the evening from June through August and December through February.

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Operations Key Message: Diversified ownership

Diversifying asset ownership

- Common to all architecture examples

Demands increased interoperability

Requires Trustworthiness

- Extends beyond cybersecurity
  - Trustworthiness.Reliability
  - Trustworthiness.Resilience
  - Trustworthiness.Safety

- Architecture defines trustworthiness requirements
  - Device level trustworthiness
  - Microgrid level trustworthiness
  - Service provider level trustworthiness

Grid operation is highly interdependent with market structure, which in turn is limited by the nature of grid operations. Operations and market evolve coincidently and interdependently.

Economics Key Message: Interoperability and Specificity

Interoperability can help to overcome the barriers of device specificity and support the marketing efforts and revenue outlook of new and existing grid services.

Organizational Strategy

1. Organizations invest in resources and capabilities that strengthen their core competencies.
2. Investments may commit an organization to certain competitive strategies and business models.
3. Firms may discover subsequent, synergistic opportunities.

Smart Grid Context

1. Asset specificity often results from efforts to meet technical requirements and contribute to a value chain.
2. Specificity may then act as a barrier to broader or further utilization of devices and systems.
3. Interoperability offers a strategy set through which to reduce “specificity barriers”.

Value chains and value networks

The value of DER and conventional assets to the electric grid will improve as interoperability enables these resources and capabilities to make additional contributions across the sector’s value network

Economics Key Message: Customer Empowerment

Interoperability is crucial to customer empowerment.

1. Enabling customers to be better informed regarding their own electricity-use decisions.
   a. Improved utilization of current assets
   b. Better decision making with respect to technological adoption
   c. Accurate signals are critical to economic efficiency

2. Enabling a plug-and-play environment.
   a. Expectation that devices purchased will work with rest of the system
   b. Devices can be selected for customer optimality
   c. Reduced entry barriers and transaction costs of integrating customer equipment

3. Informational improvements may contribute to greater customer agency

Economics Key Message: Complexity and Cost Structures

Interoperability can counter rising transaction and production costs associated with the increasing complexity of interaction among diverse organizations of varying regulatory status.

1. Value chain complexity is rising with asset specificity
2. The regulatory status of firms varies across the value chain
3. Coordinating value-adding activities is costly

} **Impact on Cost Structures**

Transaction costs are rising in salience

"Current writing has helped bring out the point that market failure is not absolute; it is better to consider a broader category, that of transaction costs, which in general impede and in particular cases completely block the formation of markets. It is usually though not always emphasized that **transaction costs are costs of running the economic system**".
(Arrow 1969)

Interoperability strategies can directly address cost escalation due to complexity

Economics Key Message: Testing and Certification

Effective and efficient testing and certification regimes are needed to ensure that devices, systems, and components perform as expected and are fit for purpose.

1. Achieving interoperability will require initial and ongoing testing of devices, systems, and systems of systems.

2. Interoperability investments constitute cooperative strategies for improving the efficiency of the electric grid.

3. Some interoperability benefits are likely to be split between stakeholder groups.

4. Testing and Certification regimes can help to identify and discipline problem areas/actors as well as inform subsequent strategy formation and product development.

Cybersecurity Key Message: Requirements & responsibility

- Cybersecurity risk profile for the smart grid
- Structural considerations
  - Business/mission requirements similar across architectures
  - Responsibilities may change, however
  - Considerations for cybersecurity activities

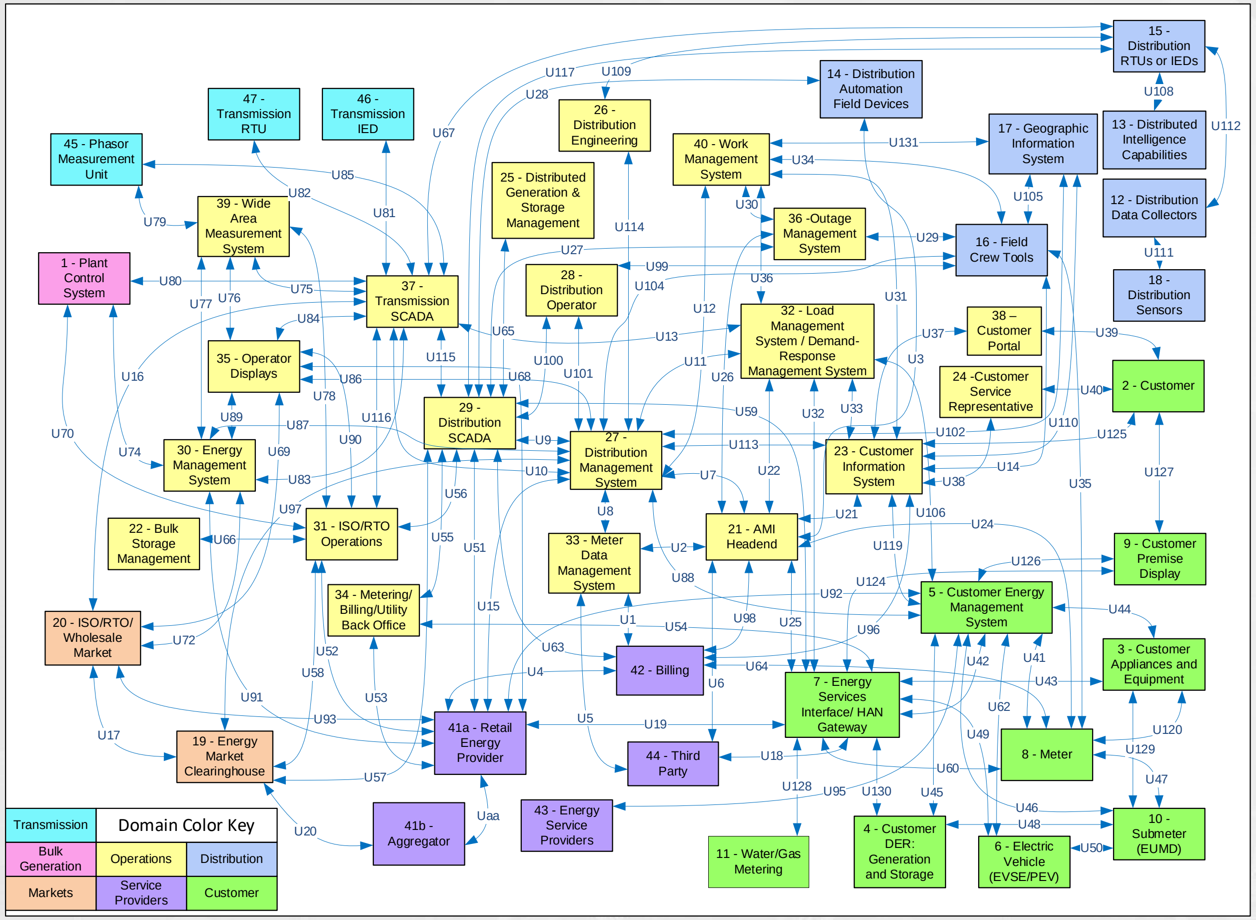
Table 2 IDENTIFY Smart Grid Profile

		Maintain Safety	Maintain Reliability+E13	Maintain Resilience	Support Grid Modernization	Considerations for Power System Owners/Operators
	Category	Subcategories				
ID	Asset Management	ID.AM-1	ID.AM-1	ID.AM-1	ID.AM-1	Knowing hardware assets is critical for maintaining safety, reliability, and resilience, as well as facilitating the transition to the modern grid. Legacy and modernized assets need to be known and understood. As modernized grids become more distributed, power system owners/operators need to be accountable for all distributed assets that they own.
		ID.AM-2	ID.AM-2	ID.AM-2	ID.AM-2	Knowing software assets is critical for maintaining reliability, and resilience, as well as facilitating the transition to the modern grid. Legacy and modernized assets need to be known and understood. This especially applies to modernized assets because the sophisticated logic that they execute is driven by software.

For more information on NIST Cybersecurity Framework: https://www.nist.gov/cyberframework

Cybersecurity Key Message: Known issues, new interfaces

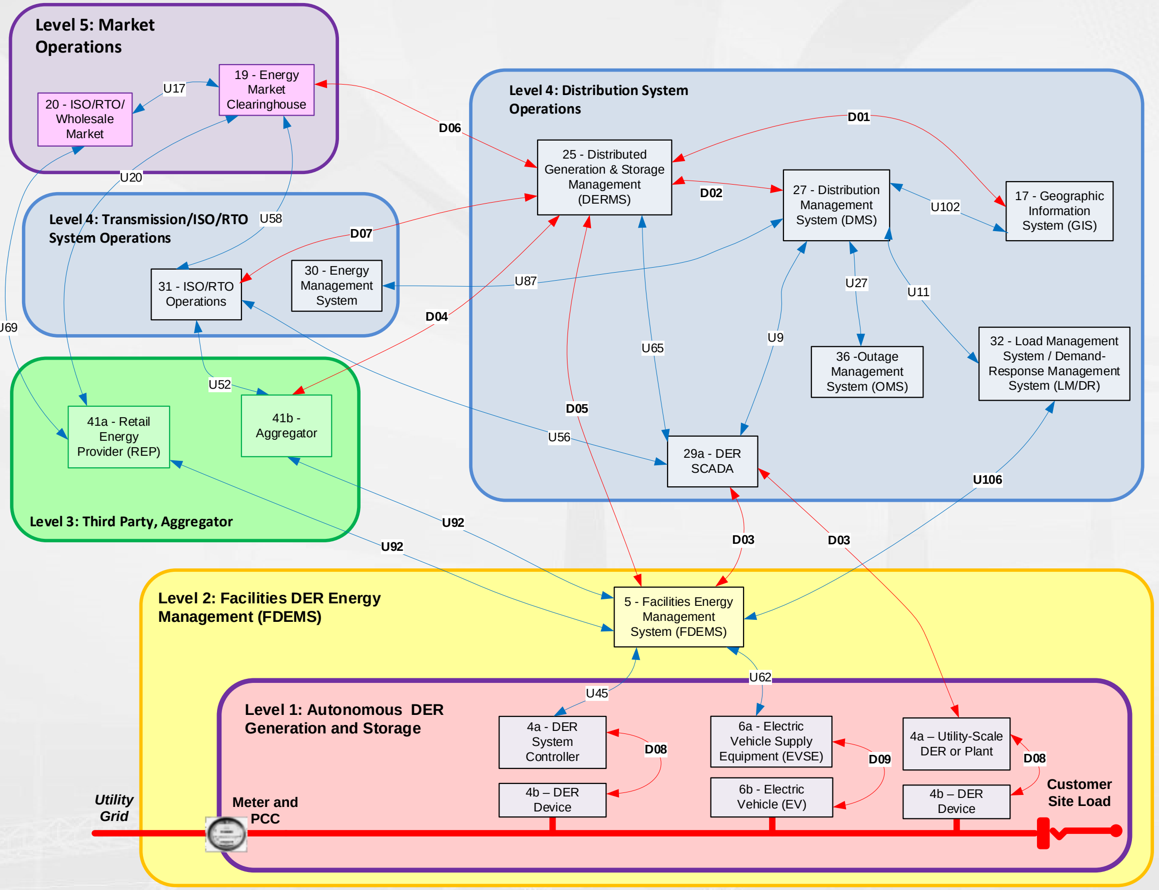
Logical Reference Model for Smart Grid Communications



Source: NISTIR 7628 Guidelines for Smart Grid Cyber Security, 2010

Logical Reference Model for High-DER Scenario

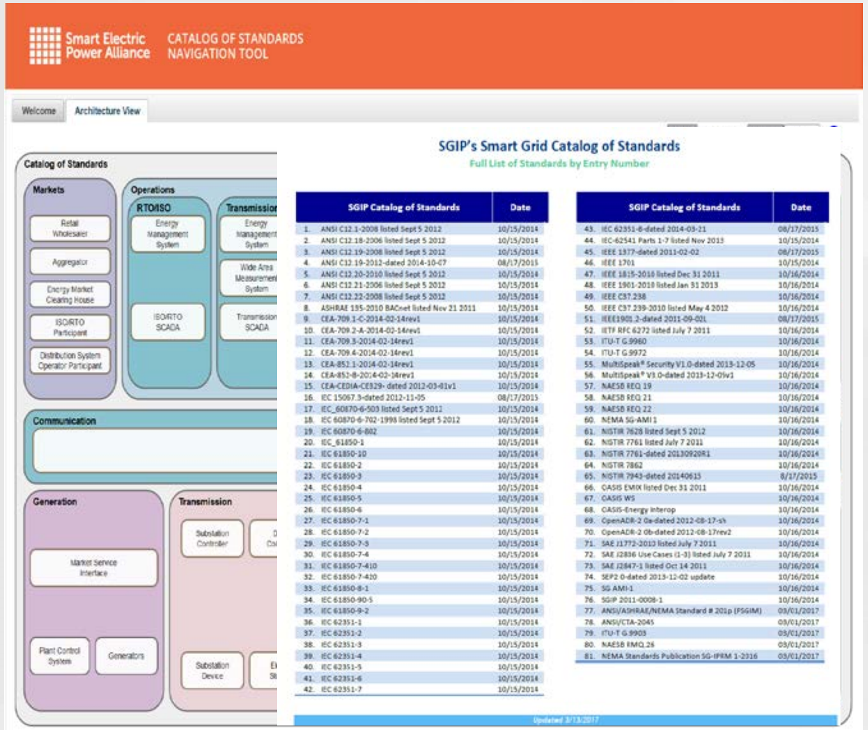
Multi-Level Hierarchical DER Scenario



Source: DRAFT NIST Interoperability Framework v4.0

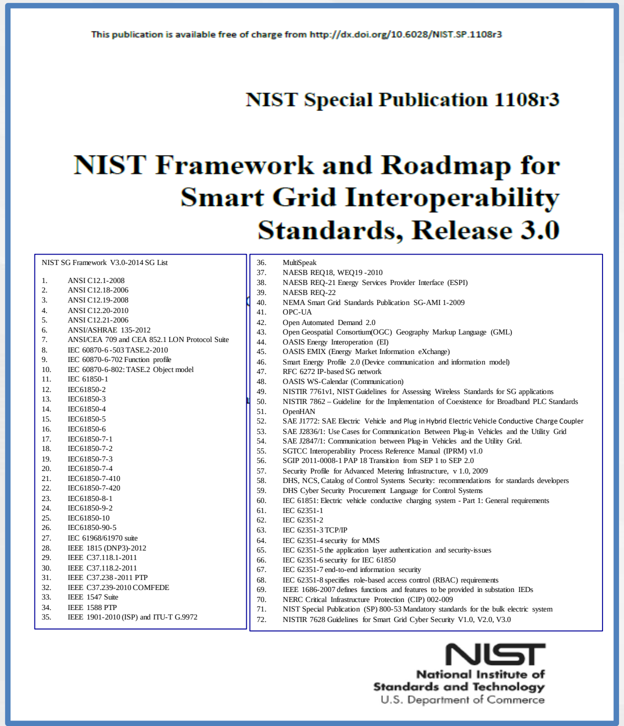
Testing & Certification: Establishing context

SEPA/SGIP SG CoS List



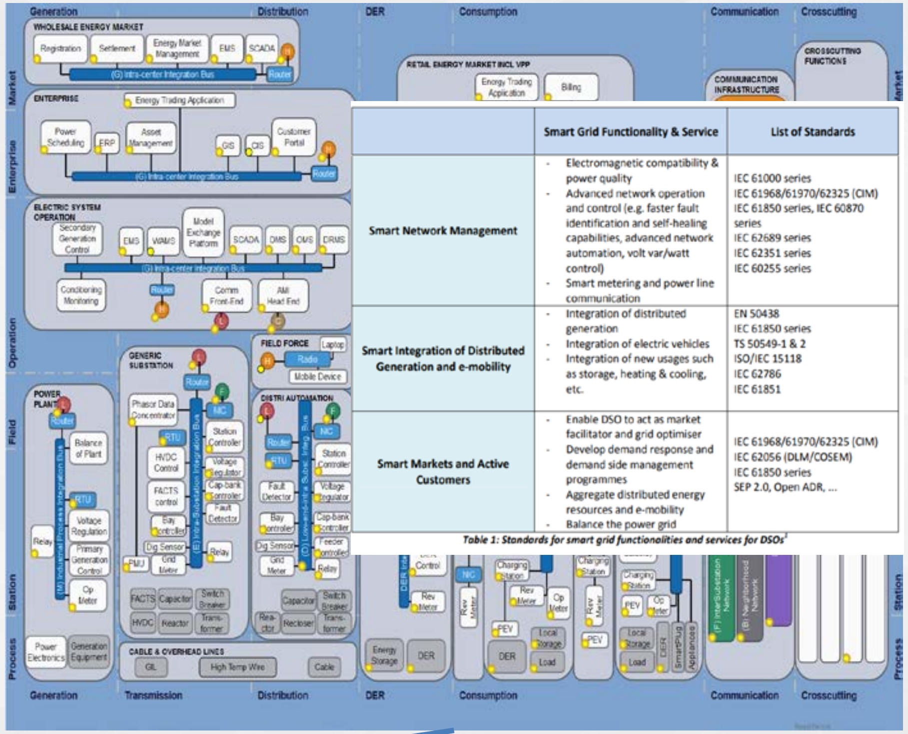
Source: http://www.gridstandardsmap.com/

Identified SG Standard List of NIST Framework R3.0



https://www.nist.gov/news-events/news/2014/10/nist-releases-final-version-smart-grid-framework-update-30

DSO Priority List



Source: https://www.edsoforsmartgrids.eu/wp-content/uploads/public/DSO-Priorities-Smart-Gird-Standardisation.pdf

New Standards:

- New Standards
- New versions of old standards

Smart Grid Standards for Evaluation (244 Standards)

Testing & Certification: Standards Evaluation Methodology

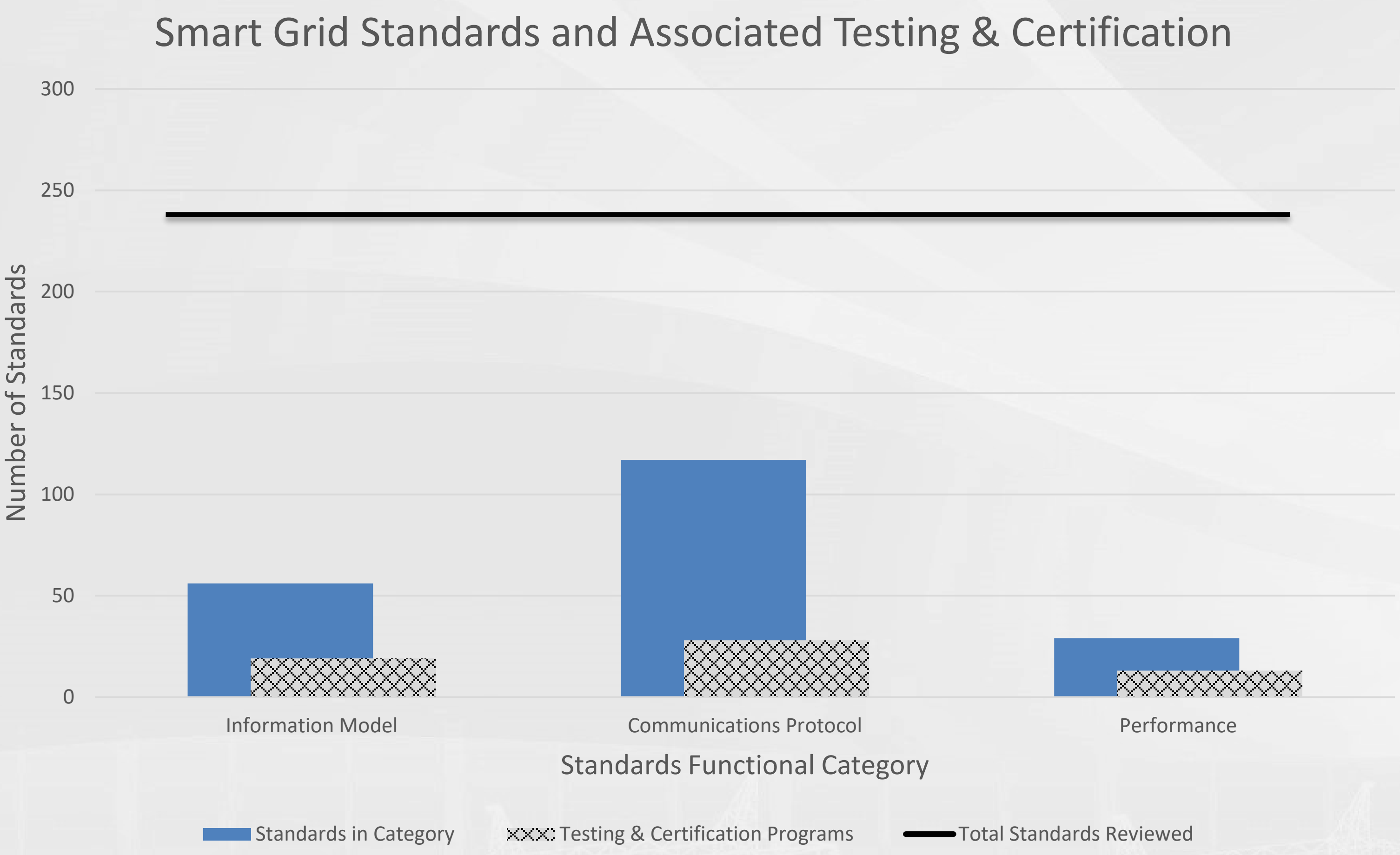
NIST Identfified SG Standards_List_April_23_2018_Song AMG.xlsx - Excel

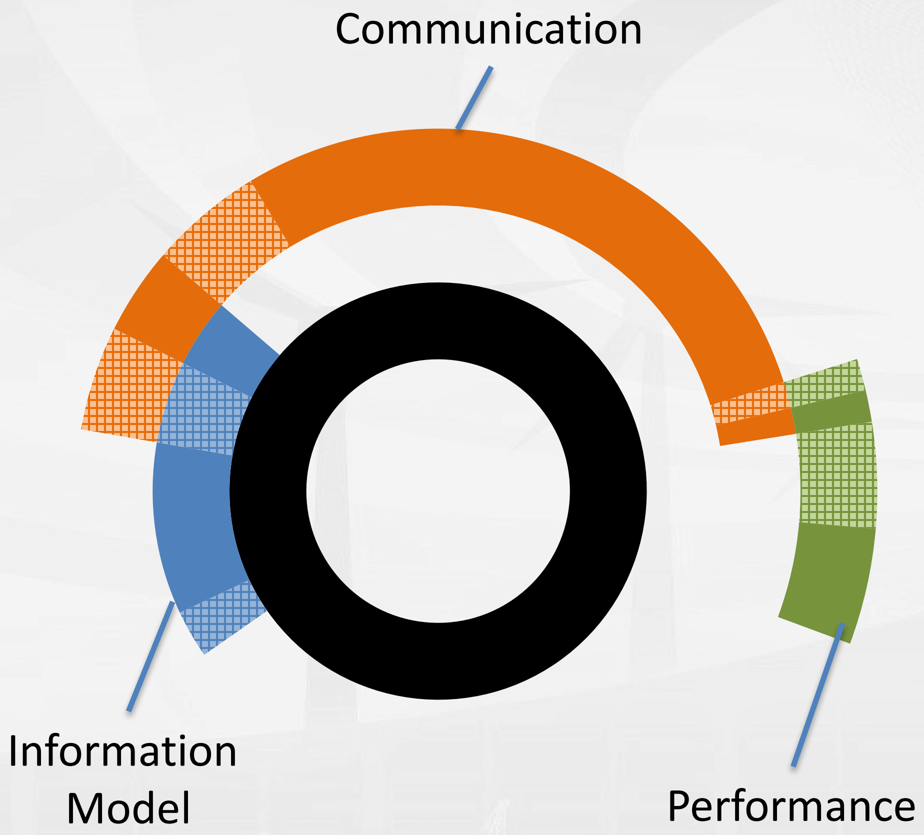
	No.	Standard Family	Standard No.	Name	Information Model	Communication	Performance	Test method	Communication Mapping	Model Mapping	Guideline & Practice	Security	(Types)	Description	Characteristics	Domain, subdomain and components	Use Cases	T&C	NIST 3.0	SEPA CoS	IEC CoS
5			ANSI C12.1-2014	ANSI C12.1-2014: Electric Meters - Code for Electricity Metering https://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%20C12.1-2014			x						Measurment performance	This standard establishes acceptable performance criteria for new types of ac watthour meters, demand meters, demand registers, pulse devices, and auxiliary devices. It describes acceptable in-service performance levels for meters and devices used in revenue metering. It also includes information on related subjects, such as recommended measurement standards, installation	This Code for Electricity Metering is designed as a reference for those concerned with the art of electricity metering, such as utilities, manufacturers, and regulatory bodies.	• Operations/distribution operations/Metering system • Transmission/substation Devices • DERs / (Field Device, meter) • Customers/Meter	personnel to determine if an outage is still valid. The OMS Poll is a multicast which can be initiated manually or automatically. • Outage Management System Poll Unicast • Outage Notification: This use case addresses the Outage Notification message generated by the Smart Meter and how this message gets generated into a trouble ticket. • Outage Restoration Notification: Utility implements integrated management of Distributed Energy Resources • Performing Real Time Price Option: This use case addresses the process of computing the Real Time Price (RTP) signals for the Smart Grid Dispatch. • Remote Programming Smart Meter: Meter Remote Connect & Disconnect: This use case addresses the messages exchanged between customer information system (CIS) and Smart Meter through	x			
6			ANSI C12.18-2006	ANSI C12.18-2006: American National Standard for Protocol Specification for ANSI Type 2 Optical Port. https://www.smartgrid.gov/document/ansi_c1218_2006ieee_p1701mc1218_protocol_specification_ansi_type_2_optical_port	x	x	x					x	Communication, information model, performance, security	This standard describes the criteria required for communications between a C12.18 Device and a C12.18 Client via an optical port. The C12.18 Client may be a handheld reader, a portable computer, a master station system or some other electronic communications device. This Standard provides details for a complete implementation of an OSI 7-layer model. The protocol specified in this document was designed to transport data in Table format. The Table definitions are in ANSI C12.19 Utility Industry End Device Data Tables.	The C12.18 Client may be a handheld reader, a portable computer, a master station system or some other electronic communications device. The C12.18 Device is An electronic communication apparatus that implements an ANSI Type 2 Optical Port for communication according to the protocol specification of this Standard. Point-to-point communications is defined as communication between C12.18 Client (reader or master) and C12.18 Device (server or apparatus) through a single optical interface.	• Operations/distribution operations/Metering system • Transmission/substation Devices • DERs / (Field Device, meter) • Customers/Meter			x	x	
			ANSI C12.19-2008	ANSI C12.19-2008: American National Standard for Utility Industry End Device Data Tables. https://www.smartgrid.gov/document/ansi_c1219_2008ieee_p1377mc12	x								Information model	This standard provides a common data structure for use in transferring data to and from utility End Devices, typically meters. The standard data structure is defined as sets of tables. The tables are grouped together into sections called decades. Each decade pertains to a particular feature-set and related function such as Time-ofuse, Load Profile, etc. Table data is transferred from or to the	This Standard defines a Table structure for utility application data to be passed between an End Device and any other device.	• Operations/distribution operations/Metering system • Transmission/substation Devices • DERs / (Field Device, meter) • Customers/Meter			x	x	

Sheet1

Ready Calculate

Testing & Certification: Preliminary Data Analysis



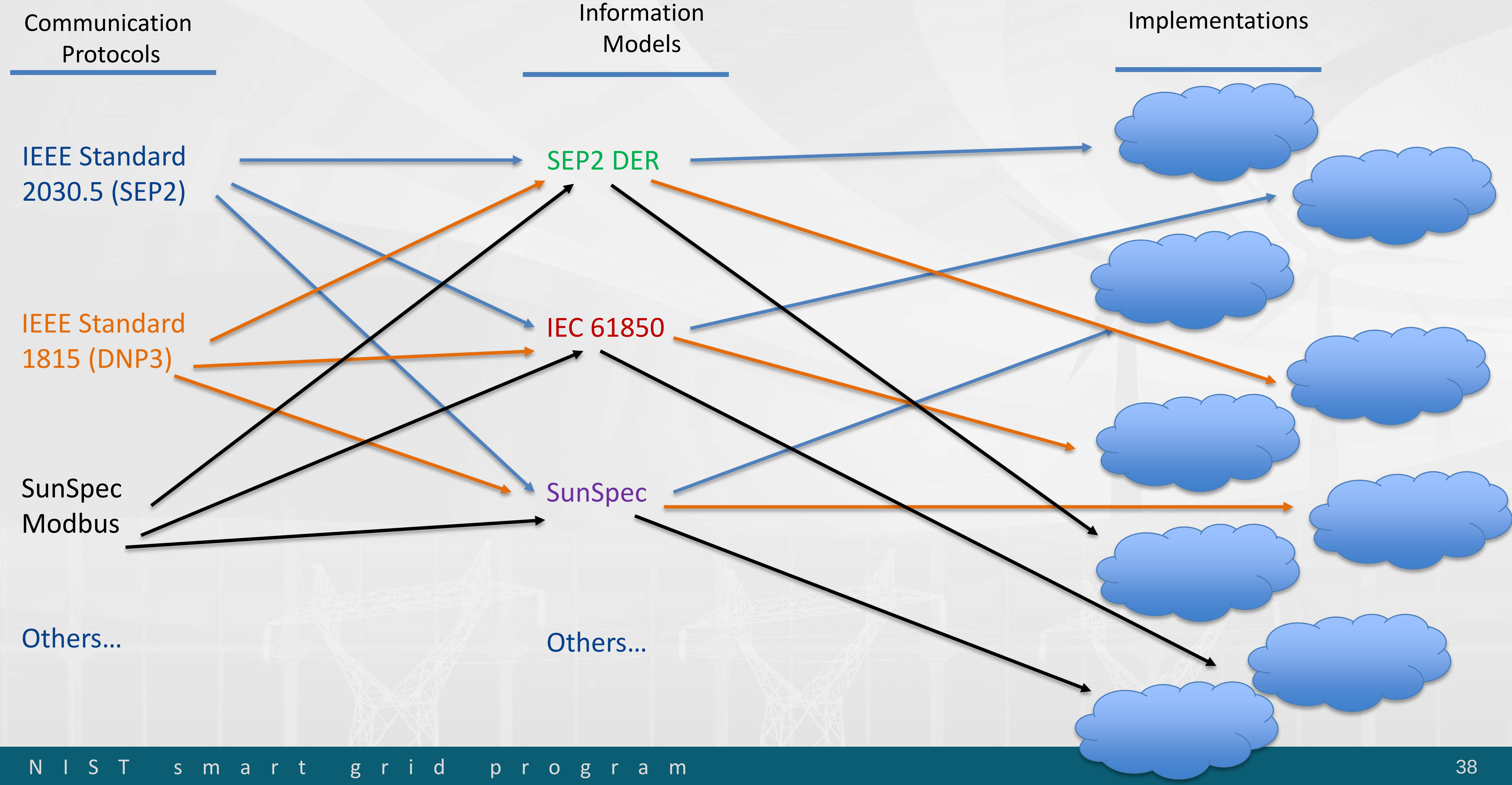


16/61 25/114 14/30

T&C Key Message: Gaps persist in assuring interoperability

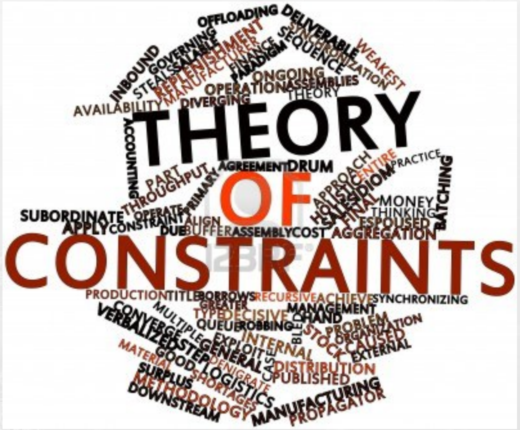
- There is a growing number of standards that are the foundation of grid modernization.
- There remains a gap in the availability of testing and certification programs to ensure that standards have been implemented appropriately and consistently to support interoperability of devices and systems.
- Even as industry coalesces around a subset of standards and options, the real universe of standards and applications is diversifying.
- Some standards are showing convergence on a subset of requirements but on parallel pathways.

T&C Key Message: Implementation complexity



T&C Key Message: Interoperability profiles

- A profile is a description of a well-defined subset of the standard that has been agreed upon by a user community, testing authority or standards body.
- The specification and use of profiles allows the interoperability gap to be narrowed by reducing the degrees of freedom of implementation flexibility in the context of interest by the device supplier, implementer and system owner.
- Interoperability profile can
  - Narrows constraints and provides uniformity
  - Supports multi-vendor interoperability
  - Lowers cost of system integration



Stakeholder Engagement: Testing and Certification Workshop

Date: July 9, 2018
Location: Washington Hilton, Washington, DC
Co-sponsor: SEPA

Objectives: To explore underlying drivers for the current state of smart grid interoperability testing and certification, and examine interoperability profiles for smart grid standards as a means to accelerate the development of testing and certification programs.

Key Questions:

- What is limiting the development and use of T&C in the smart grid ecosystem?
- What essential elements are needed to formulate an interoperability T&C program?
- How would you prioritize operational interfaces for T&C development?

Workshop webpage:
https://www.nist.gov/news-events/events/2018/07/testing-and-certification-workshop

Stakeholder Engagement: Scenarios Workshop

Date: July 24-25, 2018
Location: NIST, Gaithersburg, MD

Objectives: To review communication pathways scenarios and their relationship to grid operations, cybersecurity, economics, and associated requirements for interoperability testing and certification. We will also review a mapping of NIST's Cyber-Physical Systems (CPS) Framework aspects and concerns to the smart grid, which provide an ontology that can help clarify issues and capabilities that arise—or are needed—in this increasingly complex space.

Key Questions:

- What are the errors and deficiencies in the NIST communications scenarios?
- How can the Smart Grid Conceptual Model be used to convey grid scenarios?
- What improvements are necessary for the CPS concerns ontology for the grid?

Framework webpage:
https://www.nist.gov/news-events/events/2018/07/communication-pathways-scenarios-workshop

Stakeholder Engagement: Regional Workshops

Date: August-October, 2018
Location: Northeast, Midwest, West Coast, and Southeast
Co-sponsor: NARUC

Objectives: To explore regionally specific issues affecting grid operations and economics. The workshops will be held at state Public Utility Commissions, allowing participants to learn about interoperability issues and concerns relevant to the respective commission and its stakeholders.

Key Questions:

- Locally specific questions will be developed in partnership with NARUC and the local Commission to explore relevant aspects of the communications pathways scenarios and associated economic and operational issues.

See Framework webpage for updates:
https://www.nist.gov/engineering-laboratory/smart-grid/smart-grid-framework

THANK YOU

https://www.nist.gov/engineering-laboratory/smart-grid/smart-grid-framework

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